ONR BAA Announcement # 03-012

BROAD AGENCY ANNOUNCEMENT (BAA)

INTRODUCTION:

This publication constitutes a Broad Agency Announcement (BAA) as contemplated in Federal Acquisition Regulation (FAR) 6.102(d)(2) and Department of Defense Grant and Agreement Regulation (DODGARS) 22.315. A formal Request for Proposals (RFP), solicitation, and/or additional information regarding this announcement will not be issued.

The Office of Naval Research (ONR) will not issue paper copies of this announcement. The ONR and Department of Defense (DoD) agencies involved in this program reserve the right to select for award all, some or none of the proposals submitted in response to this announcement. ONR and other participating DoD agencies provide no funding for direct reimbursement of proposal development costs. Technical and cost proposals (or any other material) submitted in response to this BAA will not be returned. It is the policy of ONR and participating DoD agencies to treat all proposals as sensitive competitive information and to disclose their contents only for the purposes of evaluation.

I. <u>GENERAL INFORMATION</u>

1. Agency Name -

The DoD Multidisciplinary University Research Initiative (MURI), one element of the University Research Initiative (URI), is sponsored by the DoD research offices: the Office of Naval Research (ONR), the Army Research Office (ARO), and the Air Force Office of Scientific Research (AFOSR) (hereafter collectively referred to as "DoD agencies").

<u>ONR Agency Name</u>:

Office of Naval Research
800 N. Quincy Street
Ballston Centre Tower One
Arlington, VA 22217-5660

Non-ONR Agency Names:

Air Force Office of Scientific Research
4015 Wilson Boulevard, Room 713
Arlington, VA 22203-1954

Army Research Office
4300 S. Miami Blvd
Durham, NC 27703-9142

Office of the Secretary of Defense
4015 Wilson Blvd, Room 209
Arlington, VA 22203

2. Research Opportunity Title -

Multidisciplinary University Research Initiative (MURI)

3. Program Name -

Fiscal Year 2004 Department of Defense Multidisciplinary Research Program of the University Research Initiative.

4. Research Opportunity Number -

BAA 03-012

5. Response Date -

White Papers: 14 August 2003

Full Proposals: 19 November 2003

6. Research Opportunity Description -

The MURI program supports basic science and/or engineering research at institutions of higher education (hereafter referred to as "universities") that is of critical importance to national defense. The program is focused on multidisciplinary research efforts that intersect more than one traditional science and engineering discipline.

This FY04 MURI competition is specifically for the 22 topics listed below. Detailed descriptions of the topics can be found in Section VIII SPECIFIC MURI TOPICS of this BAA. The detailed descriptions are intended to provide the proposer a frame of reference and are not meant to be restrictive to the possible approaches to achieving the goals of the topic and the program. Innovative ideas addressing these research topics are highly encouraged.

White papers and proposals addressing the following topics (1) to (8) should be sent to ARO:

(1) Hybrid Synthetic Biopolymers for Multifunctional Materials
(2) Hybrid Bio-Mechanical Systems
(3) Space-Time Processing for Enhanced Mobile Ad-Hoc Wireless Networking
(4) Design and Processing of Electret Structures
(5) Giga-Hertz Electromagnetic Wave Science and Devices for Advanced Battlefield Communications
(6) Micro Hovering Aerial Vehicles with an Invertebrate Vision Inspired Navigation System
(7) Nano-Engineered Energetic Materials
(8) Human Signatures for Personnel Detection

White papers and proposals addressing the following topics (9) to (13) should be sent to ONR:

(9) Epitaxial Multifunction Materials and Applications (EMMA)
(10) Coupled Observation, Adaptive Sampling, and Forecast in the Real Environment
(11) Friction and Wear under Very High Electromagnetic Stress (Electromagnetic Launchers)
(12) Fundamental Understanding of Propellant/Nozzle Interaction to Mitigate Erosion for Very High Pressure Missile Propellant Applications
(13) Fatal Circulatory Collapse in Late-Phase Hemorrhagic Shock

White papers and proposals addressing the following topics (14) to (21) should be sent to AFOSR:

(14) Electromagnetics of Antennas and Arrays Designed Using Novel Electronic Materials and Conformal to Large Complex Bodies
(15) Nanoscale Design of Structures for Prediction and Control of Cellular Response
(16) The NanoPhysics of Electron Dynamics Near Surfaces: Key to Tomorrow's HPM Weapons
(17) Nanostructured Multi-Functional Surfaces Enabling Air and Space Vehicle Tribology
(18) Laser Cooling for Solid-State Cryogenic Refrigeration
(19) Characterization and Prediction of Turbulent Transport Properties in Nonequilibrium Flows
(20) Combined Cycle Propulsion for Efficient Hypersonic Cruise and Economic Access to Space
(21) Nanophotonics and Plasmon Optics for Optical Networks, Sources and Sensors

White papers and proposals addressing the following topic (22) should be sent to OSD:

(22) Laboratory Instrumentation Design Research

Proposals from a team of university investigators may be warranted because the necessary expertise in addressing the multiple facets of the topics may reside in different universities, or in different departments in the same university. By supporting multidisciplinary teams, the program is complementary to other DoD basic research programs that support university research through single-investigator awards. Proposals must name one Principal Investigator as the responsible technical point of contact. Similarly, one institution will be the primary awardee for the purpose of award execution. The relationship among participating institutions and their respective roles, as well as the apportionment of funds including sub-awards, if any, must be described in both the proposal text and the budget.

Historically Black Colleges and Universities and Minority Institutions (HBCU/MIs) (as defined by 10 U.S.C. 2323a (1) (c)) are encouraged to participate in the MURI program, either as the lead institution or as a member of a team. However, no specific funds are allocated for HBCU/MI participation.

7. Point(s) of Contact -

Questions of a technical nature shall be directed to the Research Topic Chief listed in the topic description.

Questions of a policy nature shall be directed to the following Point of Contact:

Office of Naval Research MURI Program Point of Contact:

Dr. Donald E. Polk
Director, Corporate Programs Division, ONR 363
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5660
Tel: 703-696-4111
Fax: 703-588-1013
Email Address: polkd@onr.navy.mil

Questions of a business nature shall be directed to the cognizant Business Point of Contact, as specified below:

ONR Business Point of Contact:

Mark Chadwick
Senior Contract Specialist
Contract and Grant Awards, Management
ONR 0253
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5660
Tel: 703-696-2599
Fax: 703-696-0066
Email Address: chadwim@onr.navy.mil

8. Instrument Type(s) -

It is anticipated that all awards resulting from this announcement will be grants.

9. Catalog of Federal Domestic Assistance (CFDA) Numbers -

12.300 Basic and Applied Scientific Research

10. Catalog of Federal Domestic Assistance (CFDA) Titles -

CFDA Title: Basic and Applied Scientific Research

11. Additional Information -

The previous MURI competition comprised ONR BAA #02-025, dated 19 July 2002, for the FY03 Multidisciplinary University Research Initiative program.

II. AWARD INFORMATION

It is anticipated the awards will be made in the form of grants to universities. The awards will be made at funding levels commensurate with the proposed research and in response to agency missions. Each individual award will be for a base period of three years, to be funded incrementally or as options. Two additional years of funding as an option are possible, to bring the total maximum term of the award to five years.

Total amount of funding for five years available for grants resulting from this FY04 MURI BAA is estimated to be about $105M, pending out-year appropriations. It is anticipated that the average award will be $1M per year, depending on the scope of the proposed research. **Depending on the results of the proposal evaluation, there is no guarantee that one or any of the proposals will be recommended for funding for any one of the topics. On the other hand, more than one proposal may be recommended for funding for a particular topic.**

III. ELIGIBILITY INFORMATION

This MURI competition is open only to, and proposals are to be submitted only by, U.S. institutions of higher education (universities), with degree-granting programs in science and/or engineering. Ineligible organizations (e.g. industry and non-profit research laboratories) or foreign universities may collaborate on the research but may not receive MURI funds. When a modest amount of additional funding for a DoD laboratory or a Federally Funded Research and Development Center (FFRDC) is necessary to make the proposed collaboration possible, such funds may be requested via a separate proposal from that organization. This supplemental proposal should be attached to the primary MURI proposal and will be evaluated separately by the responsible program manager. If approved, the supplemental proposal will be funded by the responsible agency using non-URI funds.

This year the Canadian government, through the Defense Research and Development Canada, has expressed an interest in encouraging collaboration between Canadian researchers and U.S.

researchers on the MURI program in research areas of mutual interest. Canadian university researchers, since they are not eligible to receive MURI funds, will be using their own resources that, most likely, will be provided by Canadian government granting agencies. Potential proposers are encouraged to take advantage of this opportunity to collaborate and team with Canadian researchers at no additional cost to DoD if there is suitable expertise that can enhance and strengthen the MURI project.

IV. APPLICATION AND SUBMISSION INFORMATION

1. Application and Submission Process

The proposal submission process is in two stages. Prospective proposers are encouraged to submit white papers. The reason for requesting white papers is to minimize the labor and cost associated with the production of detailed full proposals that have very little chance of being selected for funding. Based on an assessment of the white papers, the responsible Research Topic Chief will provide informal feedback to the proposers to encourage or discourage them to submit full proposals. White papers arriving after the deadline may not receive, and therefore may not benefit from, the informal feedback. However, all proposals submitted under the terms and conditions cited in the BAA will be reviewed regardless of the feedback on, or lack of, a white paper.

2. Content and Format of White Papers and Full Proposals

The proposals submitted under this BAA are expected to conduct unclassified basic research. The proposal submissions will be protected from unauthorized disclosure in accordance with FAR 15.207, applicable law, and DoD regulations. Proposers are expected to appropriately mark each page of their submission that contains proprietary information. White papers and proposals should be stapled in the upper left hand corner; plastic covers or binders should not be used. Separate attachments, such as individual brochures or reprints, will not be accepted.

White Paper Format

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double-spaced
- Font – Times New Roman, 12 point
- Number of Pages – no more than four single-sided pages (excluding cover and resumes)
- Copies – one original and two copies. Electronic copy may also be submitted by email.

Full Proposal Format : Volume 1 - Technical Proposal and Volume 2 - Cost Proposal

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double-spaced
- Font – Times New Roman, 12 point

- Number of Pages – Volume 1 is limited to no more than twenty-five (25) single-sided pages. Volume 2 is limited to no more than ten (10) single-sided pages. The cover, table of contents, and resumes are excluded from the page limitations. Full Proposals exceeding the page limit may not be evaluated.
- Copies – one original and five copies. Additionally an electronic copy may be submitted on a 3.5" Diskette or CD-ROM, (in Microsoft® Word or Excel 97 compatible or .PDF format).

White Paper Content

- Cover Page – The Cover Page shall be labeled "PROPOSAL WHITE PAPER", and shall include the BAA number, proposed title, proposer's administrative and technical points of contact, with telephone numbers, facsimile numbers, and Internet addresses, and shall be signed by an authorized officer.
- Identification of the research and issues
- Proposed technical approaches
- Potential impact on DoD capabilities
- Deliverables
- Management plan
- Potential Team
- Summary of estimated costs

White papers should be sent to the responsible Research Topic Chief in the agency specified for the topic. The white paper should provide sufficient information on the research being proposed (e.g. hypothesis, theories, concepts, approaches, data measurements and analysis, etc.) to allow for an assessment by a technical expert.

A short cover letter (one page) may be included and is excluded from the page limitation.

Full Proposal Content

The Full Proposals should be broken down into two volumes, Volume 1 – Technical Proposal and Volume 2 – Cost Proposal. Volume 1 should consist of a Cover, Table of Contents, Executive Summary, Statement of Work, Technical Approach, Project Schedule and Milestones, Assertion of Data Rights, Deliverables, Management Approach, and Personnel. Volume 2 should consist of a detailed cost breakdown by cost category for the budget periods provided below and a cost breakdown by task/subtask.

VOLUME 1: Technical Proposal

- **Cover:** A completed cover (consisting of the two single-sided pages provided in Section IX) MUST be used as the first two pages of the proposal. There should be no other page before this cover.

- **Table of Contents:** List proposal sections and corresponding page numbers.

- **Executive Summary:** Provide a summary of the research problem, technical approaches, anticipated outcome of the research if successful, and impact on DoD capabilities.

- **Statement of Work:** A Statement of Work (SOW) should clearly detail the scope and objectives of the effort and the research work to be performed under the grant if the proposal is selected for funding. It is anticipated that the proposed SOW will be incorporated as an attachment to any resultant award instrument. To this end, proposals must include a severable self-standing SOW, without any proprietary restrictions, which can be attached to a grant award.

- **Technical Approach:**

  (a) Describe in detail the basic science and/or engineering research to be undertaken. State the objective and approach, including how data will be analyzed and interpreted. Discuss the relationship of the proposed research to the state-of-the-art knowledge in the field and to related efforts in progress elsewhere. Include appropriate literature citations and references. Discuss the nature of expected results. Discuss potential applications to defense missions and requirements.

  (b) Describe plans for the research training of students. Include the number of full time equivalent graduate students, and undergraduates if any, to be supported each year. Discuss the involvement of other students, if any.

- **Project Schedule and Milestones:** A summary of the schedule of events and milestones.

- **Assertion of Data Rights:** A summary of any proprietary rights to pre-existing results, prototypes, or systems supporting and/or necessary for the use of the research, results, and/or prototype. Any data rights asserted in other parts of the proposal that would impact the rights in this section must be cross-referenced. If there are proprietary rights, the proposer must explain how these affect its ability to deliver research data, subsystems and toolkits for integration. Additionally, proposers must explain how the program goals are achievable in light of these proprietary limitations. If there are no claims of proprietary rights in pre-existing data, this section shall consist of a statement to that effect.

- **Deliverables:** A detailed description of the results and products to be delivered.

- **Management Approach:** A discussion of the overall approach to the management of this effort, including brief discussions of: required facilities; relationships with any subawardees and with other organizations; availability of personnel; and planning, scheduling and control procedures.

(a) Describe the facilities available for the accomplishment of the proposed research and related education objectives. Describe any capital equipment planned for acquisition under this program and its application to the proposed research. If possible, budget for capital equipment should be allocated to the first budget period of the grant. Include a description of any Government Furnished Equipment/Hardware/Software/Information, by version and/or configuration, that is required for the proposed effort.

(b) Describe in detail proposed subawards to other eligible universities or relevant collaborations (planned or in place) with government organizations, industry, or other appropriate institutions. Particularly describe how collaborations are expected to facilitate the transition of research results to applications. Descriptions of industrial collaborations should explain how the proposed research will impact the company's research and/or product development activities. If subawards to other universities are proposed, make clear the division of research activities, to be supported by detailed budgets for the proposed subawards.

(c) List the amount of funding and describe the research activities of the Principal Investigator and co-investigators in on-going and pending research projects, whether or not acting as Principal Investigator in these other projects, the time charged to each of these projects, and their relationship to the proposed effort.

(d) Describe plans to mange the interactions among members of the proposed research team.

(e) Identify other parties to whom the proposal has been or will be sent, including agency contact information.

- **<u>Personnel:</u>** For the MURI team, one individual should be designated as the Principal Investigator for the award, for the purpose of technical responsibility and to serve as the primary point-of-contact with an agency's technical program manager. Describe the qualifications of the Principal Investigator and co-investigators to conduct the proposed research. Include curriculum vitae and other experiences relevant to the proposed research effort.

<u>VOLUME 2: Cost Proposal</u>

The Cost Proposal shall consist of a cover and two parts: Part 1 will provide a detailed cost breakdown of all costs by cost category by the funding periods described below and Part 2 will provide a cost breakdown by task/sub-task corresponding to the task numbers in the proposed Statement of Work. Options must be separately priced.

<u>Cover:</u> The use of the SF 1411 is optional. The words "Cost Proposal" and the following information should appear on the cover:

- BAA number

- Title of Proposal
- Identity of the prime proposer and a complete list of proposed subawards, if applicable
- Principal Investigator (name, mailing address, phone and fax numbers, email address)
- Administrative/business contact (name, address, phone and fax numbers, email address) and
- Duration of effort (separately identify basic effort and proposed option)

<u>Part 1</u>: Detailed breakdown of all costs by cost category by the calendar periods stated below. For budget purposes, use an award start date of 1 May 2004. For the three-year base grant, the cost should be broken down to reflect funding increment periods of:

(1) Seven months (1 May 04 to 30 Nov 04)
(2) Twelve months (1 Dec 04 to 30 Nov 05)
(3) Twelve months (1 Dec 05 to 30 Nov 06)
(4) Five months (1 Dec 06 to 30 Apr 07)

The budget should also include an option for two additional years broken down to the following funding periods:

(1) Seven months (1 May 07 to 30 Nov 07),
(2) Twelve months (1 Dec 07 to 30 Nov 08), and
(3) Five months (1 Dec 08 to 30 Apr 09).

The annual budget should be relatively flat, i.e. about the same amount per year. (The seven-month budget and the five month budget should add up to an amount about equal to the 12 month budget.) However, if there is anticipated difficulty in effectively spending the funds at the steady-state rate for the entire first budget period, the initial seven month budget can be reduced to account for start-up effects. Similarly, the initial seven-month budget can be somewhat higher if substantial equipment funding is requested. Elements of the budget should include:

- Direct Labor – Individual labor category or person, with associated labor hours and unburdened direct labor rates
- Indirect Costs – Fringe Benefits, Overhead, G&A, COM, etc. (Must show base amount and rate)
- Travel – Number of trips, destination, duration, etc.
- Subcontract – A cost proposal as detailed as the proposer's cost proposal will be required to be submitted by the subcontractor. The subcontractor's cost proposal can be provided in a sealed envelope with the proposer's cost proposal.
- Consultant – Provide consultant agreement or other document that verifies the proposed loaded daily/hourly rate. Include a description of the nature of and the need for any consultant's participation. Strong justification must be provided, and consultants are to be used only under exceptional circumstances where no equivalent expertise can be found at a participating university.
- Materials should be specifically itemized with costs or estimated costs. An explanation of any estimating factors, including their derivation and application, shall

be provided. Include a brief description of the proposer's procurement method to be used (competition, engineering estimate, market survey, etc.).

- Other Directs Costs, particularly any proposed items of equipment or facilities. Equipment and facilities generally must be furnished by the contractor/recipient. (Justifications must be provided when Government funding for such items is sought). Include a brief description of the proposer's procurement method to be used (competition, engineering estimate, market survey, etc.).

Part 2 : Cost breakdown by task/sub-task using the same task numbers as in the Statement of Work.

3. Significant Dates and Times -

Anticipated Schedule of Events *		
Event	**Date**	**Time**
White Papers Due Date	14 August 2003	4:00 p.m. EDT
Notification of Initial DoD Evaluations of White Papers	12 September 2003	4:00 p.m. EDT
Full Proposals Due Date	19 November 2003	4:00 p.m. EST
Notification of Selection for Award	17 February 2004	
Contract Awards	1 May 2004	

***These dates are estimates as of the date of this announcement.**

4. Submission of Late Proposals –

Any proposal, modification, or revision, that is received at the designated Government office after the exact time specified for receipt of proposals is "late" and will not be considered unless it is received before award is made, the contracting officer determines that accepting the late proposal would not unduly delay the acquisition, and:

(a) the proposal was sent, to the address specified for the designated agency, by U.S. Postal Service Express Mail three or more business days prior to the date specified for the receipt of proposals (the term "business days" excludes weekends and U.S. federal holidays) ; or

(b) there is acceptable evidence to establish that it was received at the Government installation designated for receipt of proposals and was under the Government's control prior to the time set for receipt of proposals; or

(c) it was the only proposal received.

However, a late modification of an otherwise timely and successful proposal that makes its terms more favorable to the Government will be considered at any time it is received and may be accepted.

Acceptable evidence to establish the time or receipt at the Government installation includes the time/date stamp of that installation on the proposal wrapper, other documentary evidence of receipt maintained by the installation, or oral testimony or statements of Government personnel.

If an emergency or unanticipated event interrupts normal Government processes so that proposals cannot be received at the Government office designated for receipt of proposals by the exact time specified in the announcement, and urgent Government requirements preclude amendment of the announcement closing date, the time specified for receipt of proposals will be deemed to be extend to the same time of day specified in the announcement on the first work day on which normal Government processes resume.

The DoD agencies will promptly notify any proposer if its proposal, modifications, or revision was received late and will inform the proposer whether its proposal will be considered.

Note that proposals delivered by commercial carriers are considered "hand carried" and that no exception can be made to allow such proposals to be considered if for any reason they are received after the deadline. Proposers are advised that some proposals responding to past announcements that were sent via commercial carriers were delayed during shipment and arrived after the deadlines, typically by one or two days. To decrease the probability that proposals delivered by commercial carriers will arrive after the deadline and thus be ineligible to compete, proposers are urged to schedule delivery to occur several days before the deadline.

5. Address for the Submission of White Papers and Full Proposals –

White papers should be sent directly to the attention of the responsible Research Topic Chief in the agency specified for the topic as stated in the detailed topic description in Section VIII., using the addresses given below.

White papers and full proposals addressing topics (1) to (8) should be sent to the Army Research Office at the following address:

(1) For delivery by ordinary First Class or Priority Mail (but not Express Mail) through the U.S. Postal Service:
U.S. Army Research Office (FY04 MURI)
P. O. Box 12211
Research Triangle Park, NC 27709-2211

(2) For other delivery (such as Express Mail, FedEx, UPS, etc.):
U.S. Army Research Office (FY04 MURI)
for full proposals, include: ATTN: Dr. Larry Russell
for white papers, include: ATTN: list name of responsible Research Topic Chief
4300 S. Miami Blvd
Durham, NC 27703-9142
919-549-4211

White papers and full proposals addressing topics (9) to (13) should be sent to the Office of Naval Research at the following address:

Office of Naval Research
for full proposals, include: ATTN: Mailroom (MURI/ONR Code 363)
for white papers, include: ATTN: list name of responsible Research Topic Chief
800 N. Quincy Street
Arlington, VA 22217-5660
Point of Contact: Paula Barden
703-696-4111

White papers and full proposals addressing topics (14) to (21) should be sent to the Air Force Office of Scientific Research at the following address:

Air Force Office of Scientific Research
for full proposals, include: ATTN: Mailroom (MURI 04)
for white papers, include: ATTN: list name of responsible Research Topic Chief
4015 Wilson Boulevard, Room 713
Arlington, VA 22203-1954
Point of Contact: Dr. Spencer Wu
703-696-7315

White papers and full proposals addressing topic (22) should be sent to the Office of the Secretary of Defense at the following address:

Office of the Director of Basic Science
ATTN: Dr. William O. Berry
Office of the Secretary of Defense
4015 Wilson Boulevard, Room 209
Arlington, VA 22203
Point of Contact: Dr. William O. Berry
703-696-0363

NOTE: PROPOSALS SENT BY FAX OR E-MAIL WILL NOT BE CONSIDERED.

Acknowledgment of receipt of a proposal by an agency will be by way of the page in Section X. Acknowledgment Form. To obtain acknowledgment of receipt of a proposal, proposer should self-address and place a first class stamp on the form and CLIP TO ORIGINAL COPY OF THE PROPOSAL (DO NOT TAPE OR STAPLE); the form will be mailed back to the proposer shortly after the deadline for receipt of proposals.

V. <u>EVALUATION INFORMATION</u>

1. Evaluation Criteria –

White papers will be evaluated by the responsible Research Topic Chief to assess whether the proposed research is likely to meet the objectives of the specific topic, and thus whether to encourage the submission of a full proposal. The assessment will focus on scientific and technical merit (criterion 1, below) and relevance and potential contribution to DoD (criterion 2, below), although the other criteria may also be used in making the assessment.

Full proposals responding to this BAA in each topic will be evaluated using the following criteria. The first three evaluation factors are of equal importance:

(1) scientific and technical merits of the proposed basic science and/or engineering research;

(2) relevance and potential contributions of the proposed research to the topical research area and to Department of Defense missions; and

(3) impact of plans to enhance the institution's ability to perform defense-relevant research and to train, through the proposed research, students in science and/or engineering (for example, by acquiring or refurbishing equipment that can support DoD research and research-related educational objectives).

The following four evaluation criteria are of lesser importance than the above three but are equal to each other:

(4) the qualifications and availability of the principal investigator and other key research personnel;

(5) the adequacy of current or planned facilities and equipment to accomplish the research objectives;

(6) the impact of interactions with other organizations engaged in related research and development, in particular DoD laboratories, industry, and other organizations that perform research and development for defense applications; and

(7) the realism and reasonableness of cost. (Cost sharing is not a factor in the evaluation.)

2. Evaluation Panel -

White papers will be reviewed either solely by the responsible Research Topic Chief for the specific topic, or by an evaluation panel chaired by the responsible Research Topic Chief. An evaluation panel will consist of technical experts employed in the government.

Full proposals will be evaluated by an evaluation panel chaired by the responsible Research Topic Chief for the particular topic and will consist of technical experts employed in the government. Evaluation panel members are required to sign "no conflict of interest" and non-disclosure certifications.

3. Selection Process -

Full proposals will undergo a multi-stage evaluation procedure. The respective evaluation panels will review proposals first. Findings of the evaluation panels will be forwarded to senior DoD officials who will make funding recommendations to the awarding officials.

VI. AWARD ADMINISTRATION INFORMATION

1. Administrative Requirements –

- CCR - Successful proposers not already registered in the Central Contractor Registry (CCR) will be required to register in CCR prior to award of any grant, contract, cooperative agreement, or other transaction agreement. Information on CCR registration is available at http://www.onr.navy.mil/02/ccr.htm.

- Certifications – Proposals should be accompanied by a completed certification package which can be accessed on the ONR Home Page at Contracts & Grants. The certification package for Grants is entitled, "Certifications for Grants and Agreements."

2. Reporting -

In general for each grant award, annual reports and a final report are required summarizing the technical progress and accomplishments during the performance period, as well as any other reports as requested by the program manager.

VII. OTHER INFORMATION

1. Government Property/Government Furnished Equipment (GFE) and Facilities

Each proposer must provide a very specific description of any equipment/hardware that it needs to acquire to perform the work. This description should identify the component, nomenclature, and configuration of the equipment/hardware that it proposes to purchase for this effort. The purchase on a direct reimbursement basis of special test equipment or other equipment that is not included in a deliverable item will be evaluated for allowability on a case-by-case basis. Maximum use of Government integration, test, and experiment facilities is encouraged in each of the proposer's proposals.

Government research facilities and operational military units are available and should be considered as potential government furnished equipment/facilities. These facilities and resources are of high value and some are in constant demand by multiple programs. It is unlikely that all facilities would be used for the Multidisciplinary University Research Initiative program. The use of these facilities and resources will be negotiated as the program unfolds. Proposers should explain which of these facilities they recommend.

2. Use of Animals and Human Subjects in Research

If animals are to be utilized in the research effort proposed, the proposer must complete a DoD Animal Use Protocol with supporting documentation (copies of AAALAC accreditation and /or

NIH assurance, IACUC approval, research literature database searches, and the two most recent USDA inspection reports) prior to award. Similarly, for any proposal that involves the experimental use of human subjects, the proposer must obtain approval from the proposer's committee for protection of human subjects (normally referred to as an Institutional Review Board, (IRB)). The proposer must also provide NIH (OHRP/DHHS) documentation of a Federal Wide Assurance that covers the proposed human subjects study. If the proposer does not have a Federal Wide Assurance, a DoD Single Project Assurance for that work must be completed prior to award. Please see http://www.onr.navy.mil/02/howto.htm for further information.

3. Department of Defense High Performance Computing Program

The DoD High Performance Computing Program (HPCMP) furnishes the DoD S & T and DT & E communities with use-access to very powerful high performance computing systems. Awardees of DoD contracts, grants, and assistance instruments may be eligible to use HPCMP assets in support of their funded activities if Program Officer approval is obtained and if security/screening requirements are favorably completed. Additional information and an application may be found at http://www.hpcmo.hpc.mil/.

VIII. SPECIFIC MURI TOPICS

FY04 MURI Topic #1
Submit white papers and proposals to the Army Research Office

Hybrid Synthetic Biopolymers for Multifunctional Materials

Background. The focus of this topic is to combine biological systems with polymer science and materials engineering to generate new, robust multifunctional materials. To date, these disciplines have not exploited the unparalleled performance of biological systems to this end. Research has focused on synthesizing molecules that mimic protein folding or on preparing composite materials, blends, and networks that include biological molecules. These approaches have limited application and lead to problems that include aggregation, loss of supramolecular structure, and ultimately a loss of biochemical activity. What is not being explored are approaches that combine complex bio-macromolecules and polymeric materials through covalent bonding. One class of bio-macromolecule of interest for this approach is enzymes. These proteins are critical to all life on earth due to catalyzing reactions in cells, catalyzing reactions that remove toxins, and even synthesizing new enzymes. Recently experiment and computation have elucidated structure, function and catalytic pathways, thus a detailed understanding of these complicated systems is emerging. Polymers are critical to numerous Army/DoD systems, including chem/bio protective materials and coatings, composite armor, personnel ballistic protection, laser protection, and sensors. And while the design and use of new catalysts and synthesis have allowed for unprecedented control of molecular architecture and composition, this has not led to new materials and capabilities for the Army and DoD. There is still a limited "toolbox" of precursors and techniques available to generate new polymeric materials with properties of interest. Most research focuses on either modifying commercial materials or on generating designer molecules that have little hope of large-scale application. The goal of this topic is to exploit advances in both fields to generate new materials that are hybrid synthetic biopolymers. This will be accomplished by using promising biological systems as platforms to synthesize polymer chains from and by attaching bio-macromolecules covalently to polymer chains. The goal is an economically viable material that has the excellent properties of a polymeric material combined with the exceptional functionality, activity and specificity of a biological macromolecule. One benefit of this approach is that polymeric materials can be prepared cost-effectively on a large scale with controlled morphologies that can provide a favorable environment for biomolecules to function in. The hybrid materials proposed here may be designed to react to their environment and respond with biochemical activity to sense, report and decontaminate toxins and to defeat optical threats to sensors, including eyes.

Objective. The objective is to explore the fundamental science and engineering required to use biological systems as platforms to synthesize polymer chains from such that the resultant material propagates the biomolecule structure and to covalently attach biomolecules to polymers. Research will seek to exploit the unparalleled function and specificity of biological systems in a robust polymeric material to generate unique properties. Disciplines that may play a role in this research include polymer science, biochemistry, materials engineering, biology, physics, and computation and modeling.

Research Concentration Areas. <u>Materials Design</u>: Combinatorial and computational techniques may be used to facilitate the design of promising systems and to predict properties. Biological systems of interest to the Army should be identified for use rather than synthesizing mimics. Of interest are proteins, such as helical bundle proteins. They have a unique and interesting supramolecular structure with a metal center and can carry out many different chemical reactions with exceptional selectivity. This approach could be tailored and exploited for DoD for sensing, laser protection, and detoxification. Also of interest are enzymes that function under extreme conditions (i.e., temperature, pH, and salinity) to design a hybrid material, such as a responsive protective coating, that functions in a harsh environments. Other biological macromolecules may be selected if there is justification for Army interest. The key is to chose a system that can bring new capabilities to a polymeric material. <u>Preparation of Hybrid Materials</u>: A synthetic polymer will be identified that can lead to a robust, large-scale material. The choice may focus on exploiting unique self-assembly behavior where the biological moieties may be concentrated in, for example lamellae or spheres, or an organic-inorganic composite with regular hydrated nanoscale channels. The choice of polymer and biological system are interdependent and combining the two while maintaining or enhancing functionality and activity is crucial. Polymer chains may be grown from biological systems, such as enzymes.

Ordered systems such as these may be used as a support for polymer synthesis allowing the growth of polymers that follow their structure (i.e., helical). These materials are expected to have enhanced properties due to nanoscale ordering, such as light absorption for laser protection and catalytic activity for detoxification and active protection. Another approach would be to attach biological systems to polymer chains to generate a final structure and material that retains the activity of the biological system. These materials may exploit the self-assembling properties of polymers to enhance catalytic selectivity and activity through well-defined morphologies. Characterization: Biomolecule structure and function will be characterized in the hybrid material. The biochemical activity of the hybrid material must be preserved in a robust material system and will be fully characterized. The effect of the bio-macromolecules on material morphology and properties will be characterized and explored. Material properties and mechanical behavior will be characterized and optimized.

Impact. These materials will have unique properties that combine the unequaled function of biological systems with the ease of preparation, cost effectiveness, and outstanding material properties of polymers. Depending on the choice of bio-macromolecule and polymer system, several Army and DoD requirements may be targeted, including antimicrobial coatings and materials for clothing and structures, unique optical materials for laser protection, and sensing and decontaminating materials and coatings.

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FY04 MURI Topic #2
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HYBRID BIO-MECHANICAL SYSTEMS

Background: The underlying mechanisms of biomolecular recognition, signal transduction, and energy conversion can be combined with nanotechnology to create self-energized hybrid (bio-abio) multifunctional military systems. Recent breakthroughs in molecular biology, nanotechnology, and computational modeling have laid the groundwork to accomplish this objective. Molecular biology has shed new light on the relationship between molecular structure and function, and has provided materials that can respond to their environment. Nanotechnology is providing efficient fabrication methods that can control material growth and order at the molecular scale. Despite great strides made in these areas, major research challenges still exist that have not received the necessary attention. Further developments that provide a better understanding of the energy conversion and mechanics of such systems will be important for overcoming the remaining challenges.

Durability of biological systems is a key issue. Durability can be compromised by mechanical forces or by sensitivity to environmental conditions. Because biological systems usually exist in an aqueous environment, the interface between hard dry materials and soft-wet materials is important. Approaches to toughen and protect them must be developed. Mechanical forces and stresses significantly alter biomolecular function, including cell growth, differentiation, movement, signal transduction, protein secretion, and gene expression. Yet, little is known about how cells sense and respond to mechanical forces and deformations. We must understand how mechanical forces and deformations limit biological materials with respect to fracture and failure. A systematic approach is essential for determining the optimal combinations of organic and inorganic materials and for understanding how to control surface variations and adhesion of biological components so they can be integrated with receptors, effectors, and other biological processes

Another major scientific barrier is the paucity of accurate multi-scale modeling capabilities that can be used to understand these systems at scales spanning from the gene to the cell. At all scales there are modeling efforts (atomistic, molecular, and continuum), however these models must be linked together effectively. Current atomistic and molecular models are computationally prohibitive and are limited to small problems over short timescales. We must identify the most critical features from these models and pass the information to the continuum models so microscopic features key to macroscopic function can be designed and tailored. Furthermore, models must be integrated with experimental measurements, however, experiments at small spatial and temporal scales are difficult. Thus, the development of accurate instruments and experiments for small spatial and time scales are paramount. If we understand structure-property-performance relationships at all scales we will be able to engineer and optimize the self-energized hybrid systems for unparalleled performance on the macroscopic level.

Objectives: Develop a fundamental understanding of the mechanisms for the design and performance assessment of innovative hybrid systems. Develop computational and experimental mechanics tools to improve the durability of biological subsystems. Develop approaches to convert available energy from the environment to produce the desired response of the biological subsystems.

Research Concentration Areas: Interrelated theoretical, computational and experimental programs should focus on molecular biology, mechanics of materials, chemistry, physics, and computer science for the development of hybrid systems for multifunctional applications. Specific topics of multidisciplinary research include: (1) development of new control methodologies that use biological sensors, actuators and processes that can be integrated seamlessly with closed-loop biologically engineered systems, (2)new multiscale computational modeling tools for the understanding, prediction, and control of molecular biological processes, and determining the failure mechanisms associated with the system, (3) new experimental methodologies for the characterization of self-energized biological systems, (4) control of spatially varying material properties and interfacial effects.

Impact: The development of systems that use energy from their surroundings and biological processes. The systems may contain valves, actuators and sensors that function through protein folding or unfolding, self-powered molecular motors and machines, and other biological processes. Future applications include nano and micro-devices in military systems that can be used for human performance improvement, sensing and actuation, real-time self healing of damage in engineering structures, drug delivery systems, wound healing, and therapeutic processes.

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FY04 MURI Topic #3
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SPACE-TIME PROCESSING FOR ENHANCED MOBILE AD-HOC WIRELESS NETWORKING

Background: Receiver antenna beam steering is a mature technology, with a long research history. However, transmit beam steering has not been investigated as thoroughly and space-time coding is an emerging technology. There has been very little research performed on how to use these techniques effectively in a mobile ad-hoc networking (MANET) environment.
Directional antennas and transmit beam steering offers a marked enhancement of security of audio and video information transmission on the battlefield, as well as an increase in information density and a reduction of transmission times. With the ever-increasing communications requirements, the bandwidth for conventional RF military communications will soon be overloaded. Large networks of sensors, command and control of robotics, and increased situational awareness needs are some of the DoD requirements producing the exponential growth in data processing demands.
Communications capacity can be augmented by using transmit and receive antenna arrays to take advantage of the spatial diversity of the channel. Traditionally, spatial diversity has been exploited by the use of beam steering antennas. However, recently, path diversity has also been exploited using space-time coding to increase capacity. Significant amounts of research are required to exploit this increased capacity, particularly in the rapidly changing multipath conditions and geometry of the battlespace. There has been little research into networking algorithms for smart antennas, which would take advantage of this improved capacity. Particularly, medium access control (MAC) and routing need to be addressed in the context of beam steering antennas and space-time coding. Communication techniques, antenna array design, and RF propagation analysis, such as signal detection, acquisition and tracking, antenna element and array design, as well as multipath diversity, will need to be investigated in the context of MANET networking with space-time coding and beam steering antennas. Algorithms must be backward compatible, allowing for omni directional antenna systems.

Objective: Create network protocols and signal processing algorithms necessary to implement adaptive beam steering and spatial channel reuse in mobile wireless communication networks with the specific objective of enabling reuse of radio channels to double network capacity and improve protection of military communications. The research should also result in the science that will allow for the decision of which spatial reuse technique to use (space-time coding or transmit beam forming), if any, based on topology, network load, etc.

Research Concentration Areas: Research into the physics of RF propagation and signal processing; the electrical engineering of antenna array design and electronics; computer science of networking; and the mathematics of information theory and control theory, is required in the following areas:
1) Develop new link level and routing protocols that can manage the network based on the increased channel capacity of adaptive beam steering antennas and space-time coding. Techniques must also be established which can deal with the difficulty in establishing links with highly directional beams (acquisition and tracking). The new media access control and routing protocols must be able to exploit the increased capacity by fully utilizing the spatial diversity made available by beam steering and space-time coding. Protocols must be cross-layer in nature, developed in conjunction with the physical communication layer.
2) Develop new space-time coding and beam steering techniques for multi-access communications. Channel state information (CSI) estimators are of primary importance, since many space-time codes rely on this information.

3) Develop efficient signal processing techniques for space-time coding and beam steering. Beam steering and space-time decoding are computationally intensive, and therefore efficient computational techniques are required in order minimize energy consumption.
4) Develop tools to analyze and simulate space-time channel capacity and overall network performance. Channel capacity analysis must take into account imperfections in the CSI, and must quantify how different parameters affect capacity. Overall network performance analysis and simulations must be scalable, so that performance of small units to large networks can be analyzed.
5) Analyze the trade-offs between using beam-steering antennas and space-time coding. Beam-steering antennas offer LPI/LPD and less interference in a dense network environment and space-time coding offers high throughput on a single link. This trade-off should lead to strategies of under what network conditions to exploit which spatial reuse technique
6) Develop antenna geometry for beam steering antennas and space-time coding.

Impact: This technology will increase the amount of information that can be reliably and securely communicated on the battlespace and reduce transmission time. Beam steering techniques reduce the probability of detection and intercept and increases jamming resistance. The success of this research would complement the prototype networking algorithms for use with directional antennas presently being developed by DARPA.

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FY04 MURI Topic #4
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DESIGN AND PROCESSING OF ELECTRET STRUCTURES

Background: Electrets materials are characterized by the presence permanent electric dipoles and electrical charges following polarization in a strong electrical field ("poling"). There are a number of types of commercial electrets which fill a variety of applications. Electrets have the potential to be extremely useful materials in a range of applications such as sensors, acoustic devices, MEMS actuators, microelectronics systems, memory devices. In addition, electrets are playing an ever increasing role in the self-assembly and (electromagnetic field) directed assembly of molecular constructs and nanostructures into macroscopic systems of potential commercial importance. The inherent performance limitations of the currently available materials restrict applications and make some devices impractical (holographic memory is one example). These currently available materials are largely empirically discovered, and there is no clear molecular-level understanding of the mechanism for generating dipoles or storing isolated charges, and no understanding of the mechanism for dissipating charge. It is essential that these materials be understood across molecular to macroscopic scales for them meet performance demands. This will require integrating a comprehensive theory of electrets structure/property relationships with macroscopic function and finally to experiment. Unlike many areas of materials science, here theory has the potential to lead experiment. Since there is such poor understanding of electrets as a class of materials, theory may be able to rationalize the widely scattered existing examples, suggest new types of physical measurements that would provide critical understanding of mechanism and performance of electrets, and predict new types of electrets.

Objective: The objectives of the initiative are: 1) to establish the mechanism of formation of electrets, and to rationalize the development between molecular structure and electrostatic potential; 2) to explore new types of structures – both homogenous and heterogeneous – that might lead to new types of electrets; 3) to understand the dynamics of important processes involving electrets, especially those that are involved the formation of charge, and those that are involved in its dissipation – the changes in electrostatic potential as a function of mechanical motion are a key to applying electrets in many possible applications; and 4) understand the synthesis and processing relationships with performance.

Research Concentration Areas: Areas of potential interest include: 1) ab initio quantum-mechanical calculations of structure and structure-property relationships for isolated molecules and for organized arrays of charged molecular structures are of interest. 2) Within the current computational limits for first-principles quantum mechanical calculations, a study how electric poling may affect dipole orientation or give rise to charge-discharge effects (which are crucial issues for device operation) should be performed. 3) The information gathered in quantum-mechanical calculations should be used to construct realistic meso- and macro-scale models using classical atomistic and continuum methods. 4) Quantitative measurement of trapped charge densities and its relationship to atomic/molecular structure and microstructure needs to be elucidated. Finally, 5) the application of electrets to the directed assembly of nanostructures should be investigated. All of these projects should be directed to the goal of optimization of electrets performance via the as-processed structure at the nanoscale.

Impact: One of the most important outcomes of this research would be the physical understanding and the computational tools necessary to design new materials systems tailored for applications where permanent static charge of charge dipoles are important. This would include sensor materials and actuators for MEMS in soldier systems. In addition, the technology could be useful in designing self-assembling nanostructures and/or molecular machines. It could also be useful in understanding the action of biological systems (ie. ion channels) and the design of new drugs or drug delivery systems.

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FY04 MURI Topic #5
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Giga-Hertz Electromagnetic Wave Science and Devices for Advanced Battlefield Communications

Background: Proximal engagement in urban areas necessitates widely scattered high volume communication systems with a wide frequency spectrum that can be easily manipulated for secure signal processing. This necessitates adaptive reconfigurable wireless communication that encompasses part of the electromagnetic spectrum that can penetrate through and around obscurants and physical barriers effectively. Very recent research breakthrough in 10 to 100 GHz electromagnetic millimeter waves offer new means to overcome these barriers in a substantive way. For example, the known problem of detectors being swamped by the high level background GHz radiation can now be solved by using the newly demonstrated tunable band-pass and notch filters that have been constructed for the first time, operable up to 65 GHz. New solitonic GHz pulse trains have been produced that can perform a host of signal processing functions in ultra-small sized device configurations, an achievement which needs further exploration. New spin-wave dynamics has been shown to be visualizable in flight-- which will help resolve barrier problems in passing from the science to the technologies we want to develop. The confluence of these new results in the context of the Objective Force shows high promise for implementations for the envisaged near-future battlefield engagements in obscured and obstructed environments. These breakthroughs were achieved till now by a judicious orchestration of experimental and theoretical physics plus materials science efforts, with the needs of the Army in mind. Now is just the right time to merge these findings into a MURI effort so as to push this new frontier of science, to synergize and accelerate the emergence of this new technology.

Objective: The objective of this interdisciplinary research is to promote this science and develop device technology which will demonstrate adaptive signal processing capability in the 10 to 100 GHz frequency range of the electromagnetic radiation field using magnetostatic waves and magnetic solitonic trains in thin films and magnetic multi-layers. It is expected that this capability will improve the operational strategies of both the dismounted and mounted land warriors as well as the functionality of other assets in the battlefield.

Research concentration areas: The effort is to combine theoretical and experimental physics, materials science and electrical and mechanical engineering science in a synergetic mode to promote frontier research which can help the transitioning of the science into Army and DoD relevant technologies, specifically for the obscured/cluttered distributed battlefield. (1) Carry out a coordinated experimental and theoretical research effort to demonstrate signal processing functionality in the 10 to 100 GHz frequency range of the electromagnetic filed. (2) Include magnetostatic and magnetic solitonic waves, and wave trains, and study their propagation and decay properties in thin film magnetic structures. (3) Combine GHz wave sensing and frequency agility of said filters to arrive at an adaptive mode of selective use of the electromagnetic spectrum for communication between land warriors and the battlefield net. 4) Control the filter and soliton functions by externally applied fields to these device units, study the physics of reduced dimensionality and reduced size effects on the associated magnetism and magnetooptics, from macroscopic to nanoscopic levels of refinement, from Maxwell Equations down to Quantum Mechanical calculations as necessary. (5) Develop and use experimental probe means such Ferromagnetic Resonance (FR) to assess the role of decay of spin waves and magnons into phonons and establish the decay pathways in the relaxation dynamics. (6) Develop experimental probe means, such as Brillouin Scattering for the “visualization” of magnons and other means of visualizing elementary excitations, including those of phonons. (7) Grow materials in structures and conduct the appropriate Materials Science characterizations to transition this study into elemental device units, such such as adaptive phase shifters, directional couplers, circulators, notch and band-pass filters, amplifiers, oscillators, phased arrays, that use integrated frequency analyzers and sensors.

Impact: The resulting improved adaptive signal processing in the 10 to 100 GHz region of the electromagnetic field will provide the land warrior with an increased secure and adaptive means of communication, the elimination of cumbersome signal processing elements in phase array radars, better use of available bandwidth, and significantly improved connectivity resulting in improved situation awareness and Command Control.

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FY04 MURI Topic #6
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Micro hovering aerial vehicles with an invertebrate vision inspired navigation system

Background: Small rotary or flapping wing unmanned aerial vehicles (UAVs) have significant advantages over their fixed wing counterparts when the vehicle is required to hover or maneuver in, for example, building interiors, tunnels and caves. They must be extremely rugged to withstand harsh gust environments, endure obstacle collisions, operate in all types of weather, day and night, perform stationary hover and autonomously navigate in tightly constrained environments. To improve rotor/wing performance in the low Reynolds number aerodynamic regime, biomimetic unsteady mechanisms for pitching and plunging motions must be investigated. These vehicles must be capable of performing highly maneuverable and hovering flight to avoid collisions with obstacles and to maneuver effectively in confined spaces. To achieve this autonomous performance, the micro-aerial vehicle must possess a navigational control capability, which possibly could be realized through incorporation of invertebrate vision and the compound eye. Insect vision, for example, represents a visual system wherein spatial, spectral, and polarization sensitivity and sensitive and reliable movement detection are incorporated and wherein neural coding strategies deal extremely effectively with contamination by noise. In recent years, exceptional progress has been made in understanding the visual strategies that invertebrates use to cope with navigation and flight control. Desirable are panoramic insect-like based vision systems that are useful in analyzing panoramic optic flow and in detecting, chasing, or evading targets. The research in these areas, together with advances in miniaturized power sources and new, high authority micro-actuators, will lead to UAVs with unprecedented capabilities.

Objective: To conduct fundamental analytical, computational, and experimental research activities to design and develop autonomous micro-hovering air vehicles with advanced navigational and collision avoidance technology. To provide for vehicle navigation, the biomimetic foundation for exploiting the visual information capture and processing mechanisms involved in compound eye movement detection systems for greatly enhanced passive imaging and navigation capabilities for effective micro-aerial vehicle maneuverability.

Research Concentration Areas: Areas of interest for aerial vehicles include, but are not limited to, the following: (1) the understanding of the complex aerodynamic flow behavior at low Reynolds number [laminar flow, viscous drag, delayed stall, rotational circulation, wake capture, flow separation, vortex control]; (2) development of a mechanically simpler swashplateless rotor or flapping wing system that provides the pitching and rolling moments necessary for primary control, vibration reduction, and stability augmentation; (3) reconfigurable geometries such as adaptive smart skins, variable geometry rotors, etc. to improve performance and maneuverability; (4) robust insect-like navigation and flight control algorithms for obstacle avoidance and autonomous operation; (5) techniques to predict fluid-structure-control interaction; (6) active control of noise through smart-morphing of primary and auxiliary surfaces to minimize noise, reducing detectability; and (7) schemes for multiple vehicle coordination and mission execution (swarms or teams, multiple agents). (While not an area of research under this program, it is expected that it will be necessary to determine suitable adaptations of micro and mesoscale power systems for on-board power and advanced, high authority actuators to provide the necessary control forces.) Vision research to be integrated with the micro-aerial vehicle should be focused on acquiring a leap-ahead understanding of relevant concepts of design and information coding principles at the fundamental level for the biological patterns of activity supporting compound eye system function in response to visual stimuli. Included, for example, might be studies of system integrative properties as they relate to any spatial and temporal non-linearities in sensory information processing for movement detection, and how nature's optimization of the principles involved might be exploited in engineered systems for advanced image processing. Likewise, research is sought in physical and computational implementation of entirely new approaches toward dynamic integration of optics, electronics and signal processing wherein an essential element of innovative imager design is consideration of information content of an image, and wherein the relationship between physical objects and events and digital models is fully exploited.

Impact: Micro hovering aerial vehicles will provide exceptional capabilities for reconnaissance, covert imaging, urban intelligence gathering, biological and chemical agent detection, battlefield surveillance, targeting, minefield detection, early warning, communication, troop location and maneuver, terrain mapping, environmental prediction, and damage assessments. Deployed in groups, with each vehicle equipped with a different kind of sensor, they will provide a robust capability for communication, command, and control. Besides directly impacting micro-aerial vehicle navigation, robotics, surveillance, situation awareness, and stealth and camouflage defeat, it is likely that these studies will also have substantial impact in the areas of target acquisition capabilities for effective missile defense.

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FY04 MURI Topic #7
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NANO-ENGINEERED ENERGETIC MATERIALS

BACKGROUND: The current emphasis in the nanoscale energetic materials area is on the preparation and characterization of single nanoscale energetic particles. These particles are then utilized in an otherwise conventional composite formulation, incorporating the nanoparticles (typically aluminum, the fuel) in a matrix with micron-sized oxidizer particles. While there is some performance improvement, the full extent of the anticipated performance gains of the nanoscale materials have not been realized. In large measure this is due the incompatibility of the length scales. What is needed is a formulation with all constituents at the nanoscale. If this were accomplished, the reactivity of the material would be characterized by the almost premixed gas-phase reaction rates of the nanomaterials; not limited by the slower, diffusion dominated reactions of micron-sized constituents. It may also be expected that the much smaller crystalline sizes of nanomaterials would be much less susceptible to shear-induced initiation and may be less responsive to some hazards. Macroscale formulations of energetic materials that preserve the intrinsic nanoscale structure of the individual components are needed to realize the true potential of nanoscale energetic materials. An optimal material may be a macroscale three-dimensional, ordered array of nanoscale constituents, with spacing and interstitial/bonding materials chosen to optimize both stability and reactivity. At a minimum, these macroscale units would be on the order of millimeter size, which could then be processed into the centimeter to meter sizes needed for practical propellants and explosives. The advantages of this “bottom-up” approach to energetic materials are: a) developing a fundamental understanding of the evolution of properties with the size of the system, b) understanding the effects of the interaction of matter at different molecular-length scale with external stimuli, and c) developing a detailed understanding of the functionalities of matter at molecular-length scale.

RELEVANCE: Novel Energetic Materials science and technology is recognized as a critical enabler in support of changing force structure for advanced weapons platforms. Nanoenergetic materials are a key area highlighted by the DDR&E/ OUSD (S&T) “National Advanced Energetics Program”. That initiative is funding the current, first generation materials. The proposed program would support the ARL-led STO IV.WP.2003.01 “Novel Energetic Materials for the Objective Force”, the DTO WE.70 “Novel Energetics” in which ARL is a partner, the provisional SRO “Insensitive High Energy Materials” which ARL leads, the OSD Office of Munitions efforts on “Insensitive Munitions”, and DTAP/Reliance “Advanced Gun Propulsion” which ARL leads. This program will provide the next generation novel energetic materials.

OBJECTIVE: The overall goal is to engineer multi-dimensional nanoscale energetic materials systems whose energy release can be controlled in terms of its type, rate, spatial distribution, and temporal history.

RESEARCH AREAS: The goal is to manipulate individual atoms and molecules and control their assembly into a large-scale bulk energetic material. The possibility exists to build large-scale energetic materials with a very high degree of uniformity (few/no defects, perfect crystalline structure, composites with molecularly engineered uniformity, laminated composites with structures built molecularly controlled and selectable layers - - no stirring, mixing - - all done through self-assembly). It is also possible to embed molecular scale devices within the energetic matrix (embedded smart devices and sensors).
- The chemistry, physics and materials science of nanoscale energetic material preparation need to be developed, focusing on those processes that lead to well ordered structures, e.g. self-assembly, vapor deposition, etc.

- Computational methods are needed to assess the reactivity of candidate structures and to predict the stability of the energetic material structure, to both hazards (shock, spark, etc.) and to long-term degradation. These computations should also provide guidance to and receive validation from the experimental aspects of the program, specifically the formulation and characterization activities.
- Experimental methods of characterizing nanoenergetic structures are needed to verify structure and performance. This includes developments of techniques capable of the determination of the three-dimensional structure of the nanoscale assembly and the orientation and bonding of the constituents. Characterization of reaction front progress through the nanostucture is also desirable.

IMPACT: This research program will enable molecularly manipulated energetic materials and formulations with tuned chemical and physical properties, high performance, low sensitivity, and multifunctionality (a single smart material that can function as a structural material, embedded sensor, and have real-time selectable propellant, explosive, or non-lethal functionality within a precision munition). These energetic materials will also have the potential of providing factors of 3 to 4 in increased energy release rate compared with conventional formulations.

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FY04 MURI Topic #8
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HUMAN SIGNATURES for PERSONNEL DETECTION

Background: Personnel detection has always been important in warfare but in recent years it has taken a back seat to detection of vehicles and heavy weaponry. However, as war fighting moves into urban areas and insurgent or terrorist operations become prevalent, the detection of enemy personnel has reemerged as a critical underpinning requirement. Imaging sensors in the visible or infrared represent the state-of-the-art for personnel detection, but they do not work in all scenarios. Due to advances in vehicle sensing, chemical/biological detection, plus networking of acoustic, magnetic, and seismic sensors, it appears that the time is ripe to develop a personnel detection technology that can detect concealed persons or evidence of human activities, as well as, provide area surveillance and control. While the sensors that may be used for personnel detection are relatively mature, they have been primarily used for vehicle or mine detection and much less is known about the signatures when used for personnel detection.

Objective: Institute a theoretical and experimental treatment of the basic human signature phenomenology to provide a firm scientific basis for future personnel detection studies. Use this scientific base to guide sensor system development and detection techniques of personnel in complex environmental and terrain conditions.

Research Concentration Areas:
The proposal should include modeling, simulation, and validation and address each of the following areas:
Human Signature Phenomenology Study - A study of the basic physics, chemistry and biology that underlie human signatures is needed. The full spectrum of human signatures includes many different types, such as: acoustic; seismic; radar (RF to millimeter wave) and passive electromagnetic; active and passive EO/IR (electro-optic and infrared); hyperspectral, etc. In addition, basic human physical and biological processes, such as heart beat, respiration, and gait can also be used to reveal the presence of a person. Different human and environmental situations will need to be examined as the signature may decrease or change under different conditions: the target may be moving or still; sitting, lying horizontally, or standing; in urban terrain, open range, or forest/jungle environment. Ranges up to 2,000 meters should be considered. The proposer should select a reasonable set of human signatures for study with the intent to determine the most appropriate signatures for personnel detection and, perhaps, discover additional exploitable phenomena. The proposer is not required to use all of those listed above and other types of signatures might also prove useful; however, the study of human odor signatures should be de-emphasized, as it is addressed in a separate BAA. In addition, this topic is not concerned with identifying individuals but determining the general human signature.
Sensor Fusion and Networking Study – Sensor signatures of humans can be weak and extremely variable and few sensors work effectively under all conditions. As a result, none of the existing single modality signatures is likely to yield a reliable level of personnel detection accuracy by itself. Thus, fusion of sensor data and other ancillary information may be critical in achieving reliable personnel detection. While fusion techniques for vehicle detection should be exploited to the extent possible, sensor fusion algorithms that are specific to personnel detection may need to be developed due to differences in the magnitude, type, and attributes of the signatures. In addition, networking of the sensors will almost certainly be necessary for long range and broad area coverage scenarios. Fusion performed both at a single multi-sensor node and within the larger network should be considered.
Multi-Sensor Data Collection – In order to model the phenomenology study, existing literature and available data should be used to the extent possible. However, it is expected that some data collection will be required to complement the available data and to cover different scenarios for personnel. In

addition, data collection will be necessary to validate the algorithms for multi-sensor fusion for personnel detection.
New Sensor Concept Study – An investigation of concepts that include other signature modalities not listed above may be included if deemed promising.

Impact: As the Army moves to a lighter force, enemy personnel represent an increasing threat to U.S. soldiers. The ability to detect personnel without placing the soldier in harm's way would greatly enhance the soldier's survivability and lethality; for instance in recent conflicts it would have been extremely useful to be able to detect the enemy concealed in or behind vegetation, to determine if a cave were empty of personnel before entry, or to detect personnel in interior urban environments. In addition, the lighter armor on FCS vehicles makes them vulnerable to shoulder-launched, rocket-propelled grenades (RPGs); which compels a need to detect personnel with an opportunity to use those weapons.

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FY04 MURI Topic #9
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Epitaxial Multifunction Materials and Applications (EMMA)

Background: Although thin films have been investigated for many materials, it has been almost exclusively for semiconductors where techniques to control composition and structure ***at the atomic scale*** have been perfected. It is now possible to extend these techniques to more complex materials, such as oxides. The ability to precisely control the constituent cations in complex oxide crystals will allow design of any of the ferro-electric, piezo-electric, magneto-electric, superconducting, semi-magnetic and non-linear optical functions. The underlying physics is that the presence (or absence) of atomic scale defects very strongly determines the ability of a material to exhibit such long range cooperative behaviors. Complex oxide crystals, which are currently used in a multitude of discrete active devices such as sensors, transducers, passive capacitors, inductors, delay lines etc., are bulk, or at best oriented polycrystalline films deposited by non-equilibrium pulsed laser (PLD) or sputtering, e-beam evaporation etc. Crystalline thin films can be more than two orders of magnitude more sensitive than bulk or oriented polycrystalline films, as grain boundaries pin polarity leading to long hysteresis tails, high losses, etc. Controlled nucleation and deposition techniques (MBE, MOCVD etc.) have recently been demonstrated to prepare single crystal epitaxial Perovskite layers. Additionally, switching fatigue has been overcome by attention to stoichiometry (oxygen retention). Research is needed to map and understand the exceedingly large matrix of materials and functions, defining an optimal set of hetero-structure combinations, device designs and application methodologies.

Objective: To develop revolutionary techniques for single-crystal epitaxial complex-oxide thin films and multi-layer hetero-junctions (each layer performing a different active function) on semiconductors. A primary goal is that hetero-junctions, superlattices, and quantum wells between various functional crystal films will be investigated, as far as possible on SiC, nitride semi-conductors, GaAs, InP and Si. In addition, materials such as MgB_2 high temperature super-conductors and direct-gap metal silicide multilayers will be investigated (for blue emission). Archetypal compounds in the various (functional) subfamilies will be identified and parameters for their realization and compatibility with wide gap semiconducting substrates and bounding films will be determined. One example is: ($LiNiO_3$) // Ferro-electric // on SiC. This combination would provide an optically addressable MMIC switch, tunable capacitor, delay line, inductor etc, optical transistor, or electrically addressable monolithic optical router etc. Magnetic, motion, optical and electrostatic sensors can now be envisaged at the monolithic level with electrical, or optical amplifiers, transmitters etc. The matrix of possible double, triple and multiple functional devices and applications that could be executed is extremely large.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) Parameter-based Materials by Design computation of optimal complex oxide hetero-structures and quantum wells, for the many families of performance multi-functionality; (2) Experimental determination and documentation of optimal nucleation and epitaxial single crystal, hetero-structure and multiple/quantum-well growth variables; (3) Preparation and characterization of a family of Perovskite single, multi-layer, hetero-epitaxial and quantum well/super-lattices of multiple discrete and mixed functionality; (4) Preparation and characterization of archetypal of multifunctional layer structure devices of interest to DOD.

Impact: Epitaxial multifunction materials have enormous potential impact in increasing performance, reliability, flexibility, while decreasing cost, size, and power budgets of almost every electronic and sensing function, increasing the scope for intelligent remote platforms. Of immediate application are tunable passive elements in phased array MMIC, MDIC and more importantly MIXED SIGNAL (MMSIC) application on WIDE GAP and other semiconductors. Multi-parameter tunable sensors will allow combinations of very broadband thermal, acoustic, electrical, optical, magnetic signals to be detected, tuned etc. and monolithically integrated with amplifiers, transmitters etc. Thus remote, static, and moving platforms can now be equipped with reduced complexity electronic receiver, sensor and transmitter (opto)electronics.

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FY04 MURI Topic #10
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Coupled Observation, Adaptive Sampling, and Forecast in the Real Environment

Background: Advances in computational power are enabling large regions of the ocean and atmosphere to be well resolved through the use of nested models based on the Navier-Stokes equations. Advances in mathematics (dynamical systems theory) have permitted definition of coherent structures on scales ranging from planetary to laboratory through the use of 4D (space and time) data fields. The use of data fields as a basis provides more accurate and realistic realizations of the operational space than from simulations based solely on a set of nonlinear partial differential equations. Advances in satellite, line-of-sight radio, and underwater acoustic communications enable real-time data transmission that facilitates automated processing and visualization algorithms. Instantaneous information dissemination via the internet promotes the formation of distributed networks. Mobile unmanned sensor platforms, such as autonomous aerial and underwater vehicles, have also advanced recently to the point where data fields in space and time can be obtained remotely to within prescribed error bounds. These major advances in the disciplines of mathematics, computational fluid dynamics, computer science, sensor platform engineering and control, and communications need to be synthesized into a focused, multidisciplinary system to create a powerful, new predictive capability for transport, dispersion, deposition and feature evolution in the atmosphere, ocean, and land. Such synergistic sensing and prediction will provide a framework for fusing signals and optimizing estimates of the operational environment. The potential high-payoff to DOD are in areas of battlefield awareness, combating terrorism, chemical/biological defense, decision making in response and asset deployment and autonomous systems.

Objective: The objective is to accurately predict constituent transport and dispersion in the atmospheric and oceanic environment and determine constituent deposition in the forecast space. Time dependent, three dimensional computational models and time continuous three dimensional dynamical systems calculations will be initialized with data from real, distributed sensor webs in the ocean, atmosphere and on land. Mutual cuing among a variety of autonomous vehicles operating as a network will enable effective sampling of plume distributions, current patterns, and features such as convective plumes, filaments, fronts and eddies. The skill of the predicted evolutions will be maximized through feedback and re-distribution of the input signals (autonomous samplers). Such feedback is possible through recent advances in network control and communication. A central component is the design and execution of a definitive field experiment in an operationally relevant environment to test the limits of predictive techniques with their inherent mathematical and physical assumptions and numerical scale resolutions. The optimum field test would involve all elements of the battlespace (air, land, water) and would resolve the transport patterns as they are affected by the interplay of the physics in the real environment.

Research Concentration Areas: The limits to constituent transport, dispersion, and deposition predictability as they are related to sensor web adaptation and feedback will be investigated. Specific areas of interest include: (1) synergistic sensing involving advances in physics, mathematics, computer science, chemistry and engineering to provide estimates of evolving fields with minimum error through data assimilative predictive models; (2) control for adaptive and cooperative systems involving new methodologies for precision navigation, timing and coordination of dynamic groups of autonomous vehicles; (3) interoperable, adaptive, scalable networks based on scalable architectures, intelligent utilization of communication bandwidth (both radio frequency and acoustic) in noisy, latent, multipath environments, and distributed signal processing to optimize sensing aperture and minimize communication load; (4) the quantitative mathematical and physical connectivity between a dynamical systems theory analysis and the associated Navier Stokes equations, equation of state and the conservation of mass and scalar transport.

Impact: High payoff contributions to DOD needs in battlefield awareness, mine countermeasures, and combating terrorism including methods for monitoring weapons of mass destruction and tools for chem/bio defense, decision making, adaptive command and control of groups of autonomous vehicles, and more capable networked, interoperable, mobile, dynamic systems.

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FY04 MURI Topic #11
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Friction and Wear Under Very High Electromagnetic Stress (Electromagnetic Launchers)

Background: Electromagnetic acceleration of projectiles was demonstrated in 1978 at the Australian National University. Since that time, there has been continuing interest in hypervelocity electric guns including a recent US Navy demonstration of an electromagnetic launch jointly with the UK. However, severe materials wear and degradation issues have limited sustained operation of these systems. If these limitations can be overcome, the operational potential of these electric systems may be realized. Ultimately, the goal for the electromagnetic launcher is to be able to fire multiple rounds of a reasonably large projectile with an exit velocity of approximately 2.5 km/sec to travel a considerable distance. Understanding friction and wear under the extreme operating conditions of this system is crucial and little basic research has been undertaken.

A casual consideration of the issues involved leads one to suspect that the operating conditions, particularly at the interface between the rail and the projectile, are far from ordinary. The amount of charge injected to accelerate the projectile results in melting of the metal that encases the projectile and conducts current; this is particularly the case for an aluminum sabot. Because of the large amount of charge accumulated in the region of the metallic interface, one suspects that the concept of metallic band structure breaks down. Whether or not the surface layer approximates a very dense metallic plasma or some other state of matter is not known. It is certain that the conditions at the interface are sufficiently harsh that any normal material one might imagine using as a "lubricant" will either vaporize or react to become a refractory salt or acid; e.g. molydisulfide. The ensuing corrosion renders the gun useless in just a few firings. The primary issues for metallic armature railguns are how to insure low voltage conduction of current through a sliding surface contact and how to prevent gouging of the bore surfaces. Frictional and electrical heating combine to separate the rail and armature surfaces and cause a transition to a much higher voltage hybrid armature or even a plasma armature. Very little is known about the interaction between sliding friction and current conduction at high velocities or the material dependence of these effects. Use of hard surfaced (refractory or diamond) rail materials has been proposed and these will modify the transient diffusion of magnetic fields into the structures. Detailed 3D electromagnetic and thermal modeling will be essential to the study of these issues.

Objective: While the principles of the operation of the railgun seem relatively straightforward and known, the materials needed for repeated use of such a gun are not known. A successful proposal should demonstrate useful and adequate knowledge of the basic and applied research that has been undertaken with respect to EM launchers. The primary aim of this project, therefore, will be, first, to characterize, to the extent possible, the nature of the state(s) of matter in the interfacial region of the railgun between the rails and the projectile and, second, to try to find materials that will act as lubricants without seriously degrading the current conduction that is necessary to accelerate a projectile. Possibly tied to these surface states of matter, during the acceleration of a projectile, a "transition" from single to multiple current passes frequently arises; in this state, plasma arcing occurs with increased projectile drag and degraded performance of the system. This event demands much greater understanding in order to control or avoid it. As another complication, the EM launcher requires 3D computational codes to evaluate railgun barrel heating and distortion, as well as to aid the recovery of magnetic field energy to reduce the power requirements and mitigate muzzle blast and flash. These codes must also be able to calculate eddy current dissipation in the rail structure caused by the relative motion between the armature and barrel. This effect was not recognized for some time and has a significant effect on the forces available to accelerate the armature. Most of the available EM codes cannot simulate this problem.

Research Concentration Areas: Because of the unusual conditions under which a railgun operates, it is anticipated that research in this area will necessarily demand the multidisciplinary collaboration of physicists, chemists, electrical engineers, and materials scientists. In view of the anticipated difficult experimentation, a strong component of theoretical and computational effort is expected to assist in the design of experiments. Because the issues involved in making a railgun operational involve friction and wear under extreme conditions, we see a substantial opportunity for the contribution of tribologists. In view of the extreme operating conditions already mentioned, we also believe it is necessary first to build a clearer understanding of the physics and chemistry of materials under extreme electromagnetic stress before one can begin to consider whether or not operational railguns eventually may be developed. Although the related issue of the generation of sufficient electrical power to launch a projectile is very important, this MURI will focus substantially on the problems of high fields, ultrahigh charging of metallic interfaces, and nontraditional or nonstandard friction and wear. Also, while it is important to consider the issues of missile guidance, if that missile cannot be fired the question of guidance is moot. Therefore, this MURI will address the technical issue of whether or not one can realize an operational railgun that can fire many rounds before major repair.

Impact: The Navy is interested in the railgun as a kinetic weapon to incorporate onto the all electric ships that are now under consideration. The other services are interested in railguns as replacements for conventional weapons.

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FY04 MURI Topic #12
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Fundamental Understanding of Propellant/Nozzle Interaction to Mitigate Erosion for Very High Pressure Missile Propellant Applications

Background: Recent advances in missile propulsion technology offer the potential to more than double the range of a number of selected tactical missile systems, provided that the critical technical challenges related to nozzle erosion can be addressed. New composite rocket motor case technology makes it possible to increase operating pressures to 4000-5000 psi in the near term and 8000-10000 in the longer term. It is these increases in operating pressure, which enables these significant performance increases. Unfortunately, these high rocket motor operating pressures coupled with operating temperatures of >3000K result in catastrophic nozzle erosion problems, which need to be mitigated. The fundamental interactions between the propellant decomposition products and nozzle materials in these severe environments, the details of activation, the reaction mechanisms, kinetics, transport mechanisms, and other factors governing erosivity and the mitigation thereof, must be identified, characterized and reduced to practice. Although there is a body of fundamental knowledge in related areas, such as the regimes characteristic of turbine engine operating conditions, those regimes are relatively mild and not directly applicable here. The required physics, chemistry, materials science, and mechanics in the regimes of interest here are unknown.

Objective: The development of advanced solid rocket motor propellants and nozzle materials which can be tailored to survive high pressure operation requires that a fundamental understanding of both the propellant combustion products, nozzle material properties, and the processes which govern interaction between these products and various nozzle materials be developed. A multidisciplinary research initiative is proposed, focusing on combustion and redox chemistry, physics, mechanics, and materials science. Approaches will be identified and implemented to modify the propellant combustion chemistry and subsequent reaction processes with pertinent metallic and nonmetallic materials in the applicable temperature and pressure regimes. The goal is to exploit this understanding to enable tailoring of high operating pressure and temperature propulsion systems to permit both enhanced performance and mitigation of the erosion problems to meet mission requirements.

Research Concentration Areas: The research will focus on theoretical and experimental studies in the applicable temperature and pressure regimes to; (i) elucidate the chemical combustion mechanisms of selected propellant compositions, (ii) determine the combustion decomposition rates and identify product species as a function of decomposition temperature (3000-4000 K region), and pressure (1000-10000 psi region), with spatial and temporal resolution at restricted interfaces, (iii) define the physical, chemical, material, and mechanical properties of selected, both metallic and carbon based composite substrates of interest, as a function of temperature and pressure, (iv) identify and characterize key redox chemistry as a function of species concentration, temperature and pressure, (v) elucidate the processes that govern substrate material degradation, including solid-gas, liquid-gas, and gaseous phase reactions, (vi) determine binding orientations, energies, reaction probabilities, transport mechanisms, their effects and those of grain boundary and other surface chemistry, (vii) determine the effects of substrate vapor pressure and solubilities in both the solid and liquid phases on erosivity rates and mechanisms, (viii) characterize mechanical failure modes due to thermal or mechanical shock and cycling and their effects on increasing surface area and consequently, reaction rate acceleration, (ix) modify the substrate bulk and/or surface microstructure and elucidate the subsequent effects on surface chemistry and degradation either by disruption of binding sites, changing vapor pressure or changing solubilities (x) apply mathematical analyses, advanced computational simulation and modeling of these processes and effects, so that modification schemes may be optimized to maximize energy delivery while minimizing erosivity, and (xi) couple component responses to accurately determine the aggregate response using real physical, chemical, and mechanical parameters. This effort will emphasize the fundamental understanding of the complex phenomena associated with solid propellant combustion and the interaction of the decomposition products with various substrates characteristic of candidate nozzle materials in the harsh environments and regimes of interest. The accumulated effects of the various properties and processes will be investigated, validation experiments will be designed and conducted, the important physical, chemical, and mechanical parameters measured, to define the parameters and provide coefficients necessary to describe these phenomena.

Impact and Relevance: This research will enable the development and implementation of the next generation, extended range missile propulsion systems and extended range, high performance extended life Army and Naval gun systems.

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FY04 MURI Topic #13
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Fatal Circulatory Collapse in Late-Phase Hemorrhagic Shock

Background: Hemorrhagic shock is characterized by compensatory increases in peripheral resistance (vasoconstriction), which decreases peripheral tissue perfusion, as a mechanism of maintaining vital organ perfusion following significant blood loss. The goal of early resuscitation with fluids is to restore intravascular volume and thereby maintain cardiac output and tissue perfusion pressure. However, initial patient management following severe blood loss is often complicated by the fact that a number of individuals do not respond to fluid restoration and/or the use of agents that increase vasomotor activity and peripheral resistance. These individuals have progressed into a state of circulatory collapse termed irreversible shock. Unfortunately, there is no means of predicting or detecting the onset of irreversible shock, and the factors responsible for causing this condition are unknown.

Objective: The primary goal of this initiative is to increase survival of the future combat warrior. Objectives include gaining a better understanding of the underlying mechanisms of hypovolemic circulatory collapse and developing novel approaches that improve casualty outcomes. An understanding is needed of the relative roles of perfusion pressure, organs and organ systems (including the lung, heart, and vasculature), neurohumoral responses, and other local and systemic responses to sudden or severe blood loss that contribute to circulatory collapse. An additional objective is to develop technology with the ability to detect the onset of irreversible circulatory collapse and thus alert the corpsman or medic that additional intervention is needed.

Research Concentration Areas: Areas of interest for characterizing the physiologic response to severe blood loss, the failure of fluid replacement resuscitation, and the transition to circulatory collapse are listed below. This list is not exhaustive and additional approaches are encouraged.
Use of genomics, proteomics and traditional research approaches to characterize the physiologic and molecular alterations involved in the transition between reversible hypovolemia and "irreversible" circulatory collapse.
Use of integrated systems biology to elucidate the influence of individual organs or organ systems in mediating microcirculatory dysfunction and circulatory collapse.
Identification of novel therapeutics to delay or prevent late-phase circulatory collapse and the use of computational chemical modeling to construct analogs with increased duration of action.
Identification of unique biomarkers as predictors of pending circulatory collapse.
Identification of a means of detecting the onset of circulatory collapse at an early stage, thus allowing successful intervention.

Impact: Since current military operational doctrine calls for increased unit independence (extended time to evacuation or extraction), an increased incidence of fatal shock due to circulatory collapse can be predicated. It is now essential that the physiologic basis for this condition be understood. Development of novel interventions to delay or prevent the onset of hypovolemic circulatory collapse, and a technology that can detect the onset of this condition, will impact both military and civilian trauma medicine.

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FY04 MURI Topic #14
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Electromagnetics of Antennas and Arrays Designed Using Novel Electronic Materials and Conformal to Large Complex Bodies

Background: Present analytical and computational tools for evaluating the radiation properties of antennas conformal to aircraft, ships and ground vehicles are inadequate for treating many of the present, and most of the future applications. Using surface integral equations, significant accomplishments in computational electromagnetics have made it possible to evaluate the currents, fields and scattering from perfectly conducting aircraft up to the lower microwave frequencies. However, present integral equation methods aren't applicable to antennas in proximity to dielectric clad platforms or when the antennas may be on or in proximity to substrates or exotic materials that are engineered to have special propagation or scattering properties, and that may be used in scanning the array beam or altering the radiation or scattering properties.

Objective: This program will develop analysis and computational methods to evaluate the radiation and coupling of antennas on platforms that are singly or doubly curved and made of:
Conductive surfaces
Conductive surfaces covered with layered dielectric or magnetic material
Isotropic or anisotropic lossy dielectric materials
Complex materials (with or without conductive surface backing) that may include engineered surfaces that respond to applied magnetic or electric fields, or have exotic propagation characteristics.

Research Concentration Areas: The mathematical techniques employed in the solution might include integral or differential equation based methods or hybrid techniques, either in the frequency or time domain, or asymptotic solutions of Maxwell's equations, and it is most important that the studies include rigorous error estimates. Studies of canonical configurations should be included as a basis for evaluating the algorithms and understanding the resulting solutions. The analysis must include reliable physics-based models of the natural and engineered materials that are presently being considered or used for these applications. These include anisotropic dielectric and magnetic materials in the presence of external fields, manufactured "bandgap" materials, materials having nonsymmetric dispersion relations, and those having exotic "chirality" or "handedness." Interfaces between antennas on or in proximity of these complex materials and other parts of the surface need detailed consideration, as does the synthesis of material properties appropriate for control of radiation and mutual interaction.

Impact: A possibly exists for greatly reducing the large number of antennas (sometimes well over a hundred) on current DOD platforms by exploiting the phasing together with the attributes of various substrates. Additionally there would be access to highly controlled radiation patterns, low cross section scattering and having the possibility of providing communications over a wide frequency range. The ability to analyze the radiation and coupling from antennas conformal to large, complex platforms will impact vehicle design to improve stealth and enhance antenna system bandwidth. This capability will be more readily developed and transitioned by coordinating the university efforts with measurement programs at DOD laboratories.

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FY04 MURI Topic #15
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Nanoscale Design of Structures for Prediction and Control of Cellular Response

Background: Advancements in nanoscience will greatly impact development of future weapon systems and help to maintain future military dominance. An ever-increasing array of diverse nanostructures is being designed with unique properties that are suitable for special military-related applications. For example, nanostructures are being considered for extensive use in munitions, composites, electronics and lasers, even though they may not necessarily be biocompatible with personnel who develop, manufacture, transport, store, use and dispose of these materials. The same principles that bestow unique chemical activities upon nanostructures and make them attractive for technology development may also alter the fundamental way in which they interact with living cells. Thus, a weak link in nanostructure research is a failure to systematically study interactions between man-made nanomaterials (such as aluminum nanoparticles or carbon nanotubes) and living cells. But these kinds of studies are not to be justified solely on the basis of force protection, since knowledge of how nanostructures affect cells can be exploited for uses related to biotechnology and improvements in weapon systems development. What little research there is now on nano/bio interactions relies mostly on trial-and-error processes in obtaining results. There is no research with the intent of designing nanostructures for the expressed purpose of eliciting a specific cellular response or of achieving complete biocompatibility. Studies are required to understand how specificity of nanostructure design may alter cellular response. From such knowledge, fundamental principles in nanostructure design may be elucidated and applied to the development of uniquely bioactive or bio-neutral nanomaterials. Research in this area will help in designing and constructing hybrid biological systems that incorporate synthetic nanostructures and capitalize on the favorable properties derived from both the synthetic and natural worlds. Also, selective properties of the synthetic nanostructures themselves will eventually be exploited for the purpose of eliciting and controlling a desired cellular response. A proactive research program is urgently needed not just to understand and predict the outcomes of such interactions but to learn how to exploit these interactions for the benefit of the military.

Objective: This research will study, model and predict the response of a cell following its interaction with nanoscale materials. It will be important to demonstrate experimentally how certain chemical, physical and geometric properties of nanomaterials, such as size, shape, charge and composition, influence cellular uptake, disposition and fate of these nanomaterials and affect inhibitory and/or stimulatory responses at the cellular, sub-cellular and/or biomolecular levels. Experimental response data will be analyzed and modeled in relationship to specific properties and design features of the nanostructures themselves and then used to develop and test computational models that can reliably forecast a nanostructure-induced cellular response as potentially negative (toxic), positive (salutary) or neutral (biocompatible).

Research Concentration Areas: Areas of interest may include, but are not limited to: (1) microscopic, biochemical, physical and biophysical characterization of the biomolecular targets of nanostructures; (2) cellular and sub-cellular characterization of altered biological functions/behaviors/structures in response to nanostructure interactions; (3) elucidation of the biomolecular pathways and signaling networks that mediate and control the altered responses; (4) determination of scalar, structural, compositional and electronic characteristics of nanostructures that elicit desired cellular behaviors, including biocompatibility; (5) bioinformatics and computational modeling for both the independent and relational analyses between biomolecular response and nanostructure design. Proposals must show a viable teaming arrangement between biologists, chemists, mathematicians, bioinformatics specialists, and computer and material scientists.

Impact: Research breakthroughs in this area would enable advanced nano-materials to be computationally designed to elicit an array of specific biological responses or to provide complete biocompatibility. Such nanostructure control of biological behavior at the cellular level could directly impact a number of areas of importance to the Department of Defense. For example, the power to elicit specific responses could lead to novel advancements in such areas as battlefield medicine, non-lethal weapons, novel counter measures for chemical and biological defense, and biosensors. On the other hand, the capability to design biologically inert nanostructures would undoubtedly provide an enhanced measure of force protection when unwarranted and incidental exposures to nanomaterials from future weapons systems are neither advised nor avoidable.

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FY04 MURI Topic #16
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The NanoPhysics of Electron Dynamics Near Surfaces: Key to Tomorrow's HPM Weapons

Background: High power microwave (HPM) weapons concepts remain a subject of intense study. The ability of such proposed systems to damage sensitive electronics holds the promise of rapidly disrupting enemy surveillance and communications hardware at significant standoff distances to facilitate the penetration of enemy defensive perimeters by friendly forces. Over the past decade, dramatic advances have been made toward realizing useful HPM sources. These advances are largely due to the successful harnessing of the established capabilities and techniques of the microwave vacuum electronics industry. High vacuum, high cleanliness conditions have been acknowledged as being essential for achieving successful HPM sources. Nevertheless, two major scientific barriers remain before practical high-vacuum HPM sources can become a reality. First, new alternatives are necessary for generating the intense (kA/cm^2) electron beams to drive the HPM sources. At present, explosive field emission is usually used to create the needed multi-kiloampere beams. This approach results in beams of extremely low quality, the destruction of electrodes, and the creation of moving dense plasma clouds inside the HPM source. On the other hand, the thermionic cathodes used in the microwave industry have thus far proven incapable of yielding more than about 100 $amps/cm^2$. The clever use of low work-function materials and/or surface modification (including novel surface layers) might overcome these limitations. In addition, recent advances in field-emission arrays (FEAs) hold the promise for revolutionary alternatives. As an example, it has been proposed to create an actively-controlled FEA by feeding arrays of carbon nanotube emitters via individual transistor elements fabricated on a cathode surface. The second key focus area for scientific HPM source studies is that of breakdown remediation. This area has significant technical overlap with the cathode studies described above. The intense electric fields present in HPM devices are known to cause an electrical breakdown on surfaces and/or in volumes of the HPM device where the resultant free electrons and ions are undesirable. In fact, such breakdown phenomena are believed to underlie the "pulse shortening" problem that has plagued HPM source studies for decades.

Objective: To achieve new physical understanding of electron emission/absorption phenomena on a nano-scale near conducting or insulating surfaces whose detailed nanostructures are well defined. This will be used to advance the generation of intense (high current density) beams of electrons and to better control electrical breakdown phenomena in HPM devices.

Research Concentration Areas: Areas of interest include: (1) improved physical understanding of the electron field emission/absorption processes that impact both cathode and breakdown studies; (2) examination of new materials, such as composites and thin-layered structures, for next-generation cathodes and transmission windows; (3) detailed examination of FEAs emphasizing increased current density and considering the active control of each emission tip by its own transistor; (4) exploration of photonic bandgap structures as a means of reducing internal field strengths via controlled, overmoded cavities; (5) careful microscopic studies of intense field breakdown phenomena; and (6) creation of reliable predictive models for these phenomena. Successful studies of the above topics will require close cooperative research involving material scientists, physicists, electrical engineers, computer scientists, mathematicians, and chemists

Impact: Improved understanding of the detailed physics underlying electron emission and breakdown phenomena in HPM devices hold the promise of rapid breakthroughs toward the achievement of practical military systems for use in the protection of our armed forces. Furthermore, there will be numerous commercial and non-military spin-off applications in the areas of communications and radar.

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FY04 MURI Topic #17
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Nanostructured Multi-Functional Surfaces Enabling Air and Space Vehicle Tribology

Background: Current surface coating technology is primarily constrained to single-phase materials. As a result, coating friction, stiction, wear, and mechanical properties are asymptotically approaching their highest attainable values. In addition, because no single component system can adapt to widely different environments, these single-phase coatings perform optimally over a very limited range of operation and climatic conditions. For example, coating systems perform well in vacuum or air, but not in both. Nanocomposite coatings offer two powerful and novel characteristics that can overcome these shortcomings. First, nanostructures in thin coatings can be used to impart unexpected properties, such as superhardness (i.e., reports indicate that hardness exceeding that of diamond may be obtained). Second, traditional composite approaches with proper selection of phases in the nanocomposite permit constant and good tribological (friction, stiction, and wear) properties over a wide range of environments. In fact, careful consideration of composition, domain size, and particle separation can allow blending of properties that are normally mutually exclusive; these include hardness, toughness, low friction, and thermal stability.

Most research on nanostructured coatings has focused on superhardness alone leaving much untapped potential to be exploited. Space systems, for example, are assembled, stored, and launched in a terrestrial environment (moist/dry air) but are deployed in vacuum. Turbine engines experience moist/dry air and low/high temperatures. Microelectromechanical (MEMS) devices will be used on both air and space vehicles and must also resist humidity-induced stiction, which is unique to them. Oils and greases will continue to be used in the future and controlling surface chemistry via coatings will enable better additive selection and longer system life. Finally, coatings that have good tribological properties and are corrosion resistant are required, and environmental considerations drive the composition away from cadmium and chrome.

Recent advances in nanocomposite coating design and deposition have clearly shown potential to solve many commercial and DoD tribology problems. These coatings may overcome the limitations of current technologies and enable future technological objectives.

Objective: The goal of this program will be to develop a fundamental understanding of the relationships among the microstructure, chemistry, interfacial chemistry, physics, and engineering of nanocomposite coating materials for technological insertion into air and space systems (Microelectromechanical systems to momentum wheels). Nanocomposite designs will be researched to blend mutually exclusive properties and provide multifunctional coatings.

Research Concentration Areas: This program will involve detailed experimental and theoretical investigations of nanocomposite coatings for micro- and macro-scale devices. Research will cover, but not be limited to; (1) exploring nanoscopic coating architectures for imparting unique properties and for blending properties normally considered mutually exclusive, (2) evaluation of methods for exploring the mechanical, thermal, chemical, interfacial, and tribological/tribochemical properties of coatings, (3) development of nondestructive methods for the evaluation of coating properties for life/performance prediction, (4) ab-initio quantum mechanics, molecular dynamics, mesoscale, and continuum (finite element) modeling of nanocomposite coatings, and correlation of this modeling with experimental data, and (5) development and evaluation of novel mutilfuctional nanostructured coatings for DoD relevant tribological (friction, stiction, and wear) applications.

Impact and Relevance: The novel properties of nanocomposite coatings will revolutionize the design and application of numerous moving mechanical assemblies by enabling operation in the severe environments typical of DoD operations. These coatings will make possible a wide variety of DoD relevant applications including those in; MEMS moving mechanical assemblies (e.g., RF and DC switches for phased array radar, communications, and micro and pico satellites), space system control (e.g., control moment gyros, high speed flywheels, pointing and tracking gimbals), and air vehicle propulsion (e.g., bearings, struts, and turbine blade – cam anti-fretting coatings).

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FY04 MURI Topic #18
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Laser Cooling for Solid-State Cryogenic Refrigeration

Background:
Satellite-borne infrared cameras and other sensors require rugged, reliable, and vibration free cryocoolers that operate below 100K. Currently, small mechanical devices are used to cool satellite instruments. However, The mechanical complexity and vibrations of these systems pose problems for applications in high-resolution imaging of the Earth or in missile defense. Optical refrigeration has several potential advantages over these and other cooling systems. Optical refrigeration is an all-solid state technology that uses the laser cooling of solids to efficiently refrigerate to cryogenic temperatures. Simply stated, the substance is cooled when an electron is excited by an incident laser beam from the "top" of the ground state to the "bottom" of an excited state, and then, after gaining energy by phonon interaction, fluoresces as it relaxes from the center of the excited state to the center of the ground state. There are no moving parts or high-precision components in an optical refrigerator, so it is completely vibration-free, rugged, and reliable. Optical refrigeration has been demonstrated in rare-earth-doped optical solids at temperatures below 100 K. Net cooling of a semiconductor has yet to be realized, although local cooling has been observed at temperatures below 40K. While the principle of optical refrigeration is well established, many physics issues must be better understood to apply this technology. In particular, improved materials are required to cool from ambient temperatures to cryogenic temperatures with practical efficiencies. In the case of the rare-earth doped glasses and crystals, dopant-host combinations with the appropriate energy levels and purities are needed. For the semiconductor–based coolers, better heterostructures must be developed as well as new approaches for efficiently removing luminescence.

Objective:
This MURI program seeks proposals that will: 1. Improve the current understanding of laser cooling in optical solids and semiconductors by investigating fundamental properties and underlying physical principles; 2. Develop novel materials and use state-of-the-art growth and fabrication techniques to enhance material quantum efficiencies; and 3. Investigate the engineering issues that affect efficiency and provide lower operating temperatures. In particular, new approaches are sought for increasing the amount of absorbed pump radiation and improving the removal of luminescence.

Research Concentration Areas:
Studies will address experimental and theoretical issues of laser cooling in solids necessary to realize practical solid-state optical cryocoolers. These areas include but are not limited to
(i) Laser Science and Spectroscopy: Perform precision spectroscopic experiments and use other diagnostic techniques to determine material properties (e.g. excited state lifetimes, quantum efficiencies, many-body nonlinearities). Develop high power coherent light sources to study new materials and to enhance the performance of optical cryocoolers.
(ii) Material Science: Grow high-purity/high-quantum efficiency rare-earth-doped crystals and glasses. New materials with low-phonon energy and high mid-IR transparency are of great interest. Grow high-quality semiconductor heterostructures and quantum-confined systems with $>10^{-5}$ s nonradiative lifetimes.
(iii) Semiconductor Physics: Gain a better understanding of the physics of optical interactions (e.g. absorption and luminescence) at low temperatures and relatively high carrier densities in bulk and quantum confined systems. The dynamics of exciton/phonon/photon interactions under variety of excitation conditions is of particular importance.
(iv) Material Processing and Fabrication: Develop new methods to enhance external quantum efficiency of laser-cooled semiconductors. Develop high-reflectivity dielectric "super mirrors" with extremely low heating loss.

(v) Protection of Electronics: Develop new methods to protect sensors and electronics from the effects of direct laser illumination and fluorescent photon waste. Protection may be achieved by photonic band-gap materials, high quality coating and patterning, or high quality dielectric structures.

Impact:
The ability to field rugged, all-solid state cryocoolers has enormous implications for many DoD programs.   Immediate applications are for space- and airborne-based infrared sensors that require the maintenance of detector arrays at very low temperatures. In the long term, optical refrigeration may become an essential ingredient for superconductor-based electronics such as magnetometers and high-speed computers.

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FY04 MURI Topic #19
Submit white papers and proposals to the Air Force Office of Scientific Research

Characterization and Prediction of Turbulent Transport Properties in Nonequilibrium Flows

Background: Turbulent flow over a hypersonic vehicle has the dual nature of both blessing and curse. While engine designers seek new ways to promote turbulent mixing to enhance combustion within the scramjet engine, aerodynamicists strive to delay its onset and the resultant substantial increase in skin-friction drag and surface heat transfer. Currently, vehicle designers lack sufficient insight into the underlying physics to allow turbulence to be reliably predicted and scaled in the vehicle and engine design process. The influence of nonequilibrium chemistry, typical of turbulent combustion or reacting hypersonic flowfields, further complicates the prediction of turbulence properties. For flow on the vehicle surface, the bow shock wave heats the gas to high temperatures, resulting in chemical reactions, vibrational excitation and ionization within the gas. In the scramjet combustor, exothermic reactions as the fuel is burned result in similar changes to the gas state. In both cases, the energetic chemical reactions impact the turbulent fluctuations within the gas. For nonequilibrium flows with endothermic reactions the absorption of energy by the chemical reactions results in a reduction of the turbulent fluctuations as energy is removed from the flow. Conversely, in the presence of exothermic reactions the turbulent fluctuations become more intense. Thus, characterization of the effects of nonequilibrium flows on turbulence and development of accurate prediction methods for these flows are essential for the design of future hypersonic systems. Without such tools the weight penalty resulting from overly conservative designs has rendered hypersonic systems inoperable. Until recently such a research effort would have been impossible, but the development of new numerical and experimental capabilities makes the objective achievable, provided that these new capabilities are created through multi-disciplinary research.

Objective: The proposed research effort will develop the basic knowledge building blocks required for the eventual assembly of a predictive capability for nonequilibrium turbulent flows. Such a capability does not currently exist but is essential for the design of efficient hypersonic systems. Achieving understanding and successfully predicting the nature of turbulence in nonequilibrium conditions will allow vehicle designers to compensate for, or even alleviate, the detrimental effects of turbulent flow on the external surface of a hypersonic vehicle while utilizing and enhancing the beneficial aspects of the turbulent flow within the scramjet combustor. Characterization of the interaction between turbulent fluctuations and the changing chemical composition, the internal, vibrational and rotational energy modes of the gas, and the ionization state will represent significant progress towards achievement of this objective.

Research Concentration Areas: The accurate prediction of turbulent nonequilibrium flows will require a collaborative multidisciplinary effort integrating numerical simulation and experimental characterization of hypersonic fluid physics and high-temperature gas chemistry. Areas of emphasis include, but will not be limited to: 1) Coordinated experimental and numerical characterization of the chemical and thermodynamic phenomena of hypersonic turbulence. 2) Development of new numerical algorithms for efficient execution of the computationally intensive simulations required for this effort. 3) Development and application of next-generation optical diagnostic capabilities to rapidly measure the chemical composition and internal energy distribution of the gas under hypersonic flow conditions.

Impact: Development of a capability to predict the characteristics of nonequilibrium turbulent flows will profoundly impact the design of future hypersonic systems. Reduction of the uncertainty currently associated with the prediction of nonequilibrium turbulent hypersonic flows will allow vehicle designers to achieve optimization, resulting in improved vehicle propulsion efficiency, reduced thermal protection system weight and, ultimately, reduced cost for access to space. Given the slim margins by which current vehicle designs may achieve hypersonic flight, the optimizations based on an accurate prediction of the hypersonic turbulent flow may enable the operation of a hypersonic vehicle. This proposed effort will support both the Strategic Research Area of Propulsion and Energetic Devices and the DDR&E Transformation Enabling National Aerospace Initiative.

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FY04 MURI Topic #20
Submit white papers and proposals to the Air Force Office of Scientific Research

Combined Cycle Propulsion for Efficient Hypersonic Cruise and Economic Access to Space

Background: This topic responds to the DDR&E National Aerospace Initiative (NAI) interest in combined cycle propulsion for high-speed flight and low-cost space access. Over a range of Mach numbers from takeoff to hypersonic flight, different thermodynamic propulsion cycles (gas turbines, ramjets, scramjets, chemical rockets) have unique advantages. The combined cycle propulsion concept has been suggested to exploit these advantages by combining two or more of the modes of propulsion into a single propulsion system. A combined cycle engine may be an efficient means of providing propulsion throughout the entire operating envelope, from takeoff to orbit, for space access vehicles. The challenge of this approach is to minimize the penalties in: (1) size and weight for propulsion components that are used in only a portion of the flight envelope; and (2) performance and instabilities incurred when an element of the propulsion system operates far from its optimum performance conditions. Very limited experience with combined cycle propulsion exists, necessitating the creation of understanding and a knowledge base to achieve optimal design.

Objective: The objective is to study the unsteadiness of transitioning between different propulsion cycle modes and the couplings among different components (inlet, compressor, combustor, turbine, nozzle) of a combined cycle engine configuration. The uniqueness of this research lies in the focus on the transitioning and component integration. These areas of research are not addressed by current basic research, which focuses on understanding the physicochemical processes in individual engine components, primarily at optimum operating conditions.

Research Concentration Areas: The development of combined cycle engines will require several integrated research areas, including but not limited to: (1) Control of shock structure and shock/boundary layer interactions in complex geometry inlets; (2) Control of the inflow boundary layer for optimal inlet and engine performance; (3) Development of plasma-based and fluidic control devices to tailor flow paths and provide virtual surfaces to mitigate fluid dynamic instabilities with minimum variable geometry; (4) Aerothermal prediction tools that may allow for the design of durable components and the possibility of planned thermal failure of rotating turbomachinery components during high speed engine cycle operation. (5) Active and passive control of fuel-air mixing, ignition, and flameholding to enable a single combustor that operates efficiently in both subsonic (turbine, ramjet, and rocket modes) and supersonic (scramjet mode) flows in combined cycle operation. The research will involve multidisciplinary efforts in fluid mechanics and combustion, with consideration for supplementary activity in control strategies, structures, and materials.

Impact: Combined cycle propulsion is a critical enabling technology that will facilitate low-cost access to space and high-speed flight. While some limited operational experience has been achieved with systems such as the J58 engine in the SR71 aircraft and missiles that utilize rocket-boosted ramjet propulsion, the empirical knowledge base thus created is extremely limited and inadequate for the expanded challenges posed by the NAI. This topic will initiate a scientifically based approach to achieving optimal design and performance. It will be an essential first step to develop a rational design strategy for combined cycle engines.

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FY04 MURI Topic #21
Submit white papers and proposals to the Air Force Office of Scientific Research

Nanophotonics and Plasmon Optics for Networks, Sources and Sensors

Background: Research in light localization below the wavelength scale, using concepts of plasmon optics and photonic crystal nanophotonics, will lead to rapid progress in design of ultracompact integrated photonic systems. Surface plasmon waves, collective excitations for quantized oscillations of the electrons, may hold the key for opening up the nanoscopic realm. Recently, novel plasmon-based materials with feature sizes in the range of 1-50 nanometer have begun to emerge in which the optical electric field interacts directly with the material in ways reminiscent of electronics. Efficiently radiating antenna elements can be constructed for infrared or visible light. One can even envision low-loss transmission devices. These revolutionary nanostructures will greatly expand the potential applications of optical technology, allowing optical materials to be engineered, rather than treated as design constraints. The small size of these new optical elements means that quantum effects will be a significant design construct leading to a whole new class of highly efficient, low-noise switches, detectors and emitters. Appropriately designed metallic and metallodielectric nanostructures can strongly localize and manipulate light. Opportunities exist to investigate such nanostructures that guide light include ultracompact optically functional devices, light-harvesting elements for molecular and nanocrystalline-based photovoltaic devices, lithographic patterning at deep subwavelength dimensions, and aberration-free lenses that enable optical imaging with unprecedented resolution. Plasmon related effects are a key component to create optical devices considerably smaller than the propagating light's wavelength.

Objective: Novel nano-engineered optical materials and devices utilizing plasmon-related effects for high performance optical applications will be the objective. The program will address all challenges associated with developing plasmon based materials, devices, and possibly even photonic crystals that employ metallo-dielectric plasmon effects. Synthesis, processing, characterization, design and modeling, physics of the plasmon phenomena, efficient coupling to optical fields from many aspects including photonic crystals, as well as exploitation of quantum effects will all be developed for both active and passive optical components . Also of interest is the development of high intensity, propagating nanometric light sources utilizing photon/surface plasmon resonances. Reliable and scalable manufacturing techniques need to be addressed to allow the large scale production of these ultra-high performance optical materials and devices.

Research Concentration Areas: An interdisciplinary approach is required to develop synthesis and processing techniques for applying plasmon related effects to electromagnetic material design for new optoelectronic devices. Key elements are: (1) Develop fabrication methods for deep subwavelength-scale structures that control optical radiation; (2) Use full field electromagnetic simulation for structure design and performance characteristics; (3) Investigate plasmon and related phenomena, effects and properties; (4) Create and demonstrate a high intensity nanometric light source with integrated coupler; (5) Apply design and synthesis concepts in specific device-related contexts such as chip-scale components (sensors, waveguides, circuits, etc.); and (6) Develop a system-level model/theory of a photonic network and required component performance. Specific areas of research include, but are not limited to the following: (a) design high-Q plasmon based resonators; (b) design plasmonic crystals and coupling techniques; (c) develop plasmon structures to concentrate free-space optical waves, for example to efficiently couple to antenna structures; (d) investigate left-handed optical materials; (e) develop nanoprobes, nanoantennas and molecule detectors; (f) develop plasmon based optical circuit elements; and (g) develop nanofabrication technology for these plasmon devices and structures.

Impact: This program will seek to explore optical materials in the nanometer length regime for applications involving the technologically important optical frequencies and represents a revolutionary new direction in optics and photonics. Successful progress would realize such devices or concepts as: 1) ultra-sensitive hybrid plasmon/ cavity resonators having the ability to detect a single (or a few) molecule at room temperature, and/or 2) the ability to couple single sources and emitters, such as quantum dots, to free-space optical waves, which would have application to highly efficient, low-noise room temperature infrared photodetectors. Such devices could also be used to create thresholdless lasers that emit photons at regular intervals as required for high-bandwidth, secure, quantum-based communication. The ability to perform electronic-like operations on optical frequency fields would also potentially lead to ultra-high-speed processors and/or computing elements. Nanometric light sources will enable next generation approaches to photolithography and optical data storage. Advances in ultracompact integrated photonic components could lead to wireless smart networks in military applications that are power-efficient, robust, survivable and difficult to detect by remote intelligence means. Prototypical network elements would be critically dependent on waveguides, and high-efficiency sources capable of beam-steerable and tunable outputs.

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FY04 MURI Topic #22
Submit white papers and proposals to the Office of the Secretary of Defense

Laboratory Instrumentation Design Research

Background: History has shown that the invention of new research instruments often has led to a burst of scientific discoveries, advances, and creativities. In his book *Imagined Worlds* (Harvard University Press, 1977), Freeman Dyson writes that, "*the effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained.*" In this spirit, the focus of this MURI topic is to begin a systematic and sustained effort towards the development of the next generation of research tools. The goal of each funded project is not simply to purchase or to design an instrument, but to invent and develop an instrument or device having precise design specifications, assembly procedures, and process specifications that will allow it to be readily replicated by other university teams. This would make the instrument widely available to the research community. Unique scientific application and exploitation of novel characteristics and phenomena are to be emphasized. The funded instrumentation development project will be highly collaborative. Instrument and device developers must collaborate with design and manufacturing engineers in order to achieve high-performance instruments and devices that not only operate, but have also incorporated such desirable features as reliability, operability, maintainability, and affordability. An associated goal of the program is to enhance the development of a new cadre of scientists and engineers who are experts in , and place high intellectual value, in the art and science of building instruments, devices, and equipment. Proposed projects must describe the educational impact of the project on students not only in the Principal Investigator's research area, but also on collaborating engineering students in the areas of design and manufacturing.

Objective: To investigate, invent, and develop the next generation of research instruments to allow us to make scientific measurements that we have not been able to do, and to develop a new generation of scientists and engineers with expertise in the design and manufacturing of innovative instruments and devices.

Research Concentration Areas: The topic is open to any and all innovative ideas in any and all scientific disciplines of interest to DoD. Of interest are instruments and devices that would transform the way we do scientific investigations that would lead to new discoveries for DoD applications. For that reason, no examples are given. Incremental upgrades of existing instruments and devices will not be considered. Furthermore, this program is not intended for the purchase of instrumentations, as is the case in the Defense University Research Instrumentation Program. Innovative proposals that address the objectives of this topic, considering the background described above, are highly encouraged.

Impact: A new way of thinking about instruments and devices that would allow us to make scientific measurements that we have not been able to do before, and would enable unprecedented advances in research and development in areas of interest to DoD. The projects funded in this topic will also enhance the development of a new generation of scientists and engineers with expertise in the design of scientific instruments that are easy to operate, reliable, manufacturable, and affordable.

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IX. COVER

Submitted in response to FY 2004 DoD Multidisciplinary Research Program of the University Research Initiative BAA

TECHNICAL PROPOSAL COVER
(This form must be completed and submitted as the cover of the proposal)

BAA NUMBER:_________________

1. THE PRINCIPAL INVESTIGATOR (One name only)

____ ______________________________________
(Title) (First Name) (MI) (Last Name) PI Signature (please use blue ink)

(______)__________________ (_______)__________________ _________________________________
(Phone Number) (FAX Number) (E-mail address)

____
(Institution/Department/Division)

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(Street/PO Box/Building)

____
(City) (State) (Zip Code)

Other universities involved in the MURI team if any ____

____

CURRENT DoD CONTRACTOR OR GRANTEE: YES_____NO_____

If yes, give Agency, Point of Contact, Phone Number:____

____

2. THE PROPOSAL:

____
(Title; be brief and descriptive; do not use acronyms or mathematical or scientific notation)

1 MAY 2004 to 30 APR 2007 — Proposed Base Period
1 MAY 2007 to 30 APR 2009 — Proposed Option Period
_______________________________ Your Institution's Proposal Number

Submitted to: ___________ _______ ____
DOD Agency/ Topic #/ Topic Title

Total funds requested from DOD:

_____________ + ________________ = ____________________
3-year base total 2-year option total 5-year total

OTHER AGENCIES RECEIVING THIS RESEARCH FUNDING REQUEST
(e.g., NSF, DOE, NASA, NIH). Please identify agency(ies) and give Name(s) and Phone Number(s) of Point(s) of Contact at those agencies:

____

3. MINORITY INSTITUTION: _____ Check here if the academic institution named above is qualified to be identified by the Department of Education as a minority institution (i.e., a historically Black college or university, Hispanic-serving institution, Tribal college or university, or other institution meeting statutorily-defined criteria for serving ethnic groups that are underrepresented in science and engineering). The Department of Education maintains the list of U.S. accredited postsecondary institutions that currently meet the statutory criteria for identification as minority institutions at the following web site: http://www.ed.gov/offices/OCR/minorityinst.html

4. THE INSTITUTION: NAME AND ADDRESS OF UNIVERSITY OFFICIAL AUTHORIZED TO OBLIGATE CONTRACTUALLY AND WITH WHOM BUSINESS NEGOTIATIONS SHOULD BE CONDUCTED:

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(Title) (First Name) (MI) (Last Name)

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Signature of Authorized University Official Date
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[1] The DoD is required by 31 U.S.C. 7701 to obtain each recipient's TIN (usually the Employer Identification Number) for purposes of collecting and reporting on any delinquent amounts that may arise out of the recipient's relationship with the Government.

[2] The institution's number in the data universal numbering system (DUNS) is a unique nine digit (all numeric) identification number for organizations. Dun & Bradstreet Corporation assigns it. You can receive a DUNS number by calling Dun & Bradstreet at 1(800) 333-0505 or go to the Dun & Bradstreet Web site at http://www.dnb.com/dnbhome.htm.

X. ACKNOWLEDGMENT FORM

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Date:

Dear Proposer:

Your FY2004 Multidisciplinary URI research proposal has been received at:

ARO ____ ONR _____ AFOSR _____

____and will be evaluated, Control Number_______________

____will not be evaluated for the following reason(s):

Letters announcing award recommendations will be mailed by about mid-February 2004.